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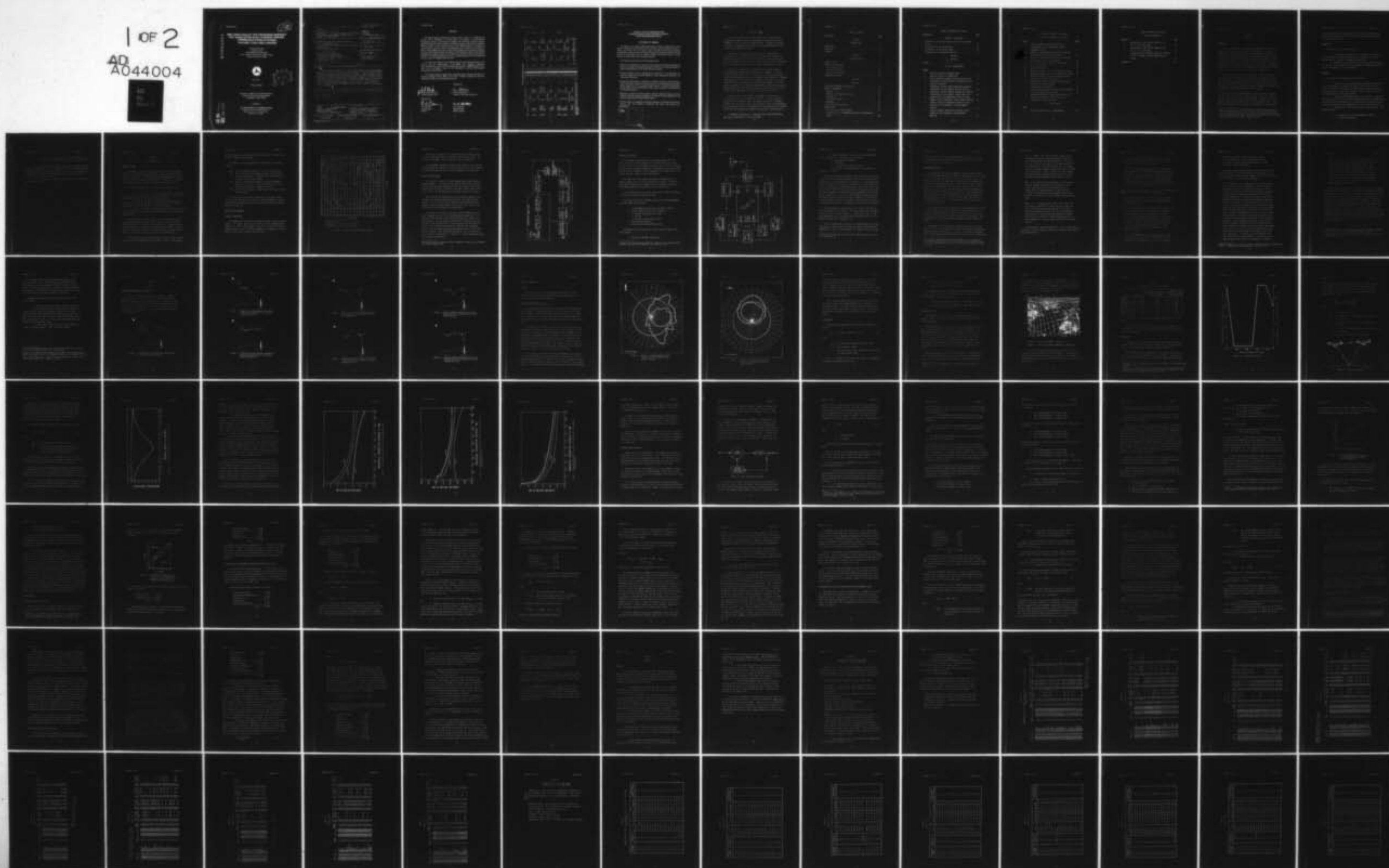

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EMC ANALYSIS OF THE PROPOSED AEROSAT VHF SUBSYSTEM WITH CURRENT INBAND COMMUNICATIONS SYSTEMS VOLUME I (USA AND CANADA)

IIT Research Institute
Under Contract to
DEPARTMENT OF DEFENSE
Electromagnetic Compatibility Analysis Center
Annapolis, Maryland 21402

May 1977

FINAL REPORT

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16. Abstract

Information and guidelines are presented pertaining to the electromagnetic compatibility (EMC) of ground and airborne equipments in the Aeronautical Mobile VHF Service with the proposed AEROSAT VHF avionics. Volume I provides general guidelines for AEROSAT avionics compatibility with the VHF environment and predicted interactions with aeronautical mobile VHF equipments in the United States and Canada. Volume II addresses the worldwide VHF environment. The frequency bands considered are 125.4-126.0 MHz and 131.4-132.0 MHz. The analysis is based on the VHF frequency assignments in use when the study was performed (1975); co-channel operation of AEROSAT and air traffic control (ATC) stations is not considered.

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PREFACE

The Electromagnetic Compatibility Analysis Center (ECAC) is a Department of Defense facility, established to provide advice and assistance on electromagnetic compatibility matters to the Secretary of Defense, the Joint Chiefs of Staff, the military departments and other DoD components. The Center, located at North Severn, Annapolis, Maryland 21402, is under executive control of the Assistant-Secretary of Defense for Communication, Command, Control, and Intelligence and the Chairman, Joint Chiefs of Staff, or their designees, who jointly provide policy guidance, assign projects, and establish priorities. ECAC functions under the direction of the Secretary of the Air Force and the management and technical direction of the Center are provided by military and civil service personnel. The technical operations function is provided through an Air Force sponsored contract with the IIT Research Institute (IITRI).

This report was prepared for the Systems Research and Development Service of the Federal Aviation Administration in accordance with Interagency Agreement DOT-FA70WAI-175, as part of AF Project 649E under Contract F-19628-76-C-0017, by the *staff of the IIT Research Institute* at the Department of Defense Electromagnetic Compatibility Analysis Center.

To the extent possible, all abbreviations and symbols used in this report are taken from American Standard Y10.19 (1967) "Units Used in Electrical Science and Electrical Engineering" issued by the USA Standards Institute.

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METRIC CONVERSION FACTORS

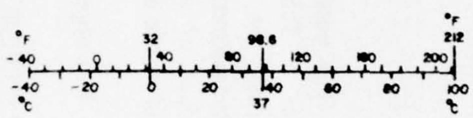
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT STAFF

STATEMENT OF MISSION

The mission of the Spectrum Management Staff is to assist the Department of State, Office of Telecommunications Policy, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radio-frequency spectrum.

This objective is achieved through the following services:

- Planning and defending the acquisition and retention of sufficient radio-frequency spectrum to support the aeronautical interests of the nation, at home and abroad, and spectrum standardization for the world's aviation community.

- Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, standards, criteria, measurement equipment, and measurement techniques.

- Conducting electromagnetic compatibility analyses to determine intra/inter-system viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend the aeronautical services spectrum from encroachment by others, and to provide for the efficient use of the aeronautical spectrum.

- Developing automated frequency-selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.

- Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

EXECUTIVE SUMMARY

As a joint venture of the United States (US), Canada and the European Space Agency (ESA), an experimental aeronautical satellite (AEROSAT) system is presently being developed. AEROSAT will provide evaluation of communications and position-fixing techniques for aircraft flying transoceanic routes.

The Federal Aviation Administration (FAA) is directing US participation in the program. FAA has requested that the DoD Electromagnetic Compatibility Analysis Center (ECAC) determine means by which the AEROSAT satellite-to-aircraft VHF link can operate compatibly with the inband international air-to-ground communications systems.

Operational conditions were evaluated to determine possible interactions between AEROSAT and the VHF user community. Usage in the VHF frequency band (125.4-132.0 MHz) was ascertained and representative VHF equipment electrical parameters were determined. AEROSAT EMC equipment specifications and operational constraints were established to preclude interference to the VHF-user community. The FAA-proposed frequency plan, whereby AEROSAT frequencies would be assigned midway between the 50-kHz channels presently used in the 125.4-126.0 and 131.4-132.0 MHz frequency bands, was shown to be feasible.

Only the 1975 US and Canadian environment was addressed as a direct application of the generalized analysis. Further analysis is required for the Atlantic area. The results show that, if AEROSAT avionics and satellite receivers are developed to meet the recommended adjacent-channel rejection requirements, no restrictions need be placed on AEROSAT VHF frequency assignments for operation in North America.

Co-channel operation of Aerosat and other VHF-users was not considered in this analysis.

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SECTION 1

INTRODUCTION

BACKGROUND

In 1974 a Memorandum of Understanding[1] (MOU) was signed by the United States, Canada, and the European Space Agency (formerly the European Space Research Organization). The MOU provides for the implementation of an Aeronautical Satellite System (AEROSAT) to experiment with and develop an operational capability for improving oceanic air traffic control. The system will be initially deployed over the Atlantic Ocean but expansion to the Pacific is planned. AEROSAT will provide two-way voice and data communications, via satellite, between ground locations and aircraft flying over the oceanic area.

Part of the AEROSAT system will include a satellite-aircraft link operating in the VHF band. This band is presently being used internationally for air-to-ground communications by commercial and private aircraft (hereafter referred to as the terrestrial system in this report). It is desired that no changes be made to the terrestrial systems for compatible operation of the two systems.

The Federal Aviation Administration (FAA), which is directing the U.S. participation in the AEROSAT program, tasked the Electromagnetic Compatibility Analysis Center (ECAC) to conduct an electromagnetic compatibility (EMC) analysis of the AEROSAT system. In addition to determining the EMC between the AEROSAT VHF subsystem and

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[1] *Annex I and Annex II to the Memorandum of Understanding on a Joint Programme of Experimentation and Evaluation Using an Aeronautical Satellite Capability Between the US Dept. of Transportation, Federal Aviation Administration (FAA), the European Space Research Organization (ESRO), and the Gov. of Canada*, August 2, 1974.

systems operating in the same band, ECAC was asked to determine the extent of the interference-free areas within which AEROSAT-equipped aircraft could operate.

OBJECTIVES

The objectives of this task were to:

1. Determine the compatibility of AEROSAT-VHF subsystem with the present terrestrial systems, and if required, to develop methods that will provide for compatible operation.

2. Recommend guidelines, utilizing methods developed, that will provide for compatible operation between the AEROSAT-VHF subsystem and its environment in the US and Canada.

APPROACH

The analysis was performed in five (5) steps.

1. Technical data and operational procedures were collected on the systems being considered from ECAC files and other sources. Data on the AEROSAT system was provided to ECAC by the FAA, while data on the terrestrial systems was provided to ECAC by both the FAA and Aeronautical Radio Incorporated (ARINC).

2. Potential interference paths were determined. Satellite-to-aircraft or aircraft-to-satellite communications in the AEROSAT system may be sources of interference to, or experience interference from air-to-ground or ground-to-air communications in the terrestrial systems.

3. The parameters affecting the analysis were studied. These parameters were:

   a. scintillation of transionospheric signals,
   b. multipath propagation,

c. the effects of antenna patterns on propagation and,

d. receiver performance in the presence of interference.

4. The results of the parameter analysis were applied to the potential interference paths to determine if the proposed AEROSAT system can operate compatibly with the terrestrial systems. Simple procedures were developed for AEROSAT implementation that will not require any changes to the terrestrial system.

5. The procedures developed in step 4 were applied to the US and Canadian systems.

SECTION 2

SYSTEM DESCRIPTION

AEROSAT SYSTEM

The AEROSAT system will provide two-way voice and data communications, via satellite, between ground locations and aircraft flying over the oceanic area. A requirement is that AEROSAT operate in all oceanic areas not covered by the terrestrial system and it is desired that AEROSAT operate in all areas, both oceanic and over land.

Three frequency bands will be utilized by the AEROSAT system.

1. *125.4 to 126.0 MHz; 131.4 to 132.0 MHz (VHF)*. Satellite-to-aircraft links will use the 125.4 to 126.0 MHz band. Aircraft-to-satellite links will use the 131.4 to 132.0 MHz band.
2. *1543.5 to 1660 MHz*. Satellite-to-aircraft links will use the 1543.5 to 1578.5 MHz band. Aircraft-to-satellite links will use the 1622.5 to 1636.5 MHz and 1645 to 1660 MHz band.
3. *5000 to 5250 MHz*. Ground-to-satellite links will use the 5000 to 5125 MHz band. Satellite-to-ground links will use the 5125 to 5250 MHz band.

Two geostationary satellites will be located between 15 and 40 degrees West longitude for the Atlantic system. Initially, three ground terminals will be built, one in Europe, one in Canada, and one in the United States. Avionics installations will be made on selected commercial aircraft: Boeing 747, Lockheed L-1011, and Douglas DC-10. The VHF avionics will be installed on the 747 aircraft only.

The two-satellite system has the potential for providing aircraft position fixing by comparing the two satellite signals. The program

will experiment with aircraft position fixing and will develop operational standards and procedures.

The AEROSAT system development will approximately follow this schedule.

1976: Design of ground terminals, avionics, and satellites.

1977: Begin construction of ground terminals, first avionics units, and satellites. Complete construction and begin testing of first avionics units.

1978: Complete construction and begin testing of ground terminals and satellites. Begin construction of the remaining avionics units. Begin system test.

1979: Launch first satellite. Additional system tests. Launch second satellite.

The system will become fully operational in the early 1980's. FIGURE 1 shows the areas to be initially served by AEROSAT. System performance requirements must be met in all areas where the satellite elevation exceeds 10°.

AEROSAT VHF SUBSYSTEM

General Description

The AEROSAT VHF subsystem is designed to handle analog or digital signals. The analog signals will be FM voice with a maximum peak deviation of 1.5 kHz. The frequency range will be limited to voice frequencies (300 to 3,000 Hz) and a pre-emphasis, de-emphasis of 6 dB per octave will be used, to reduce the noise level.

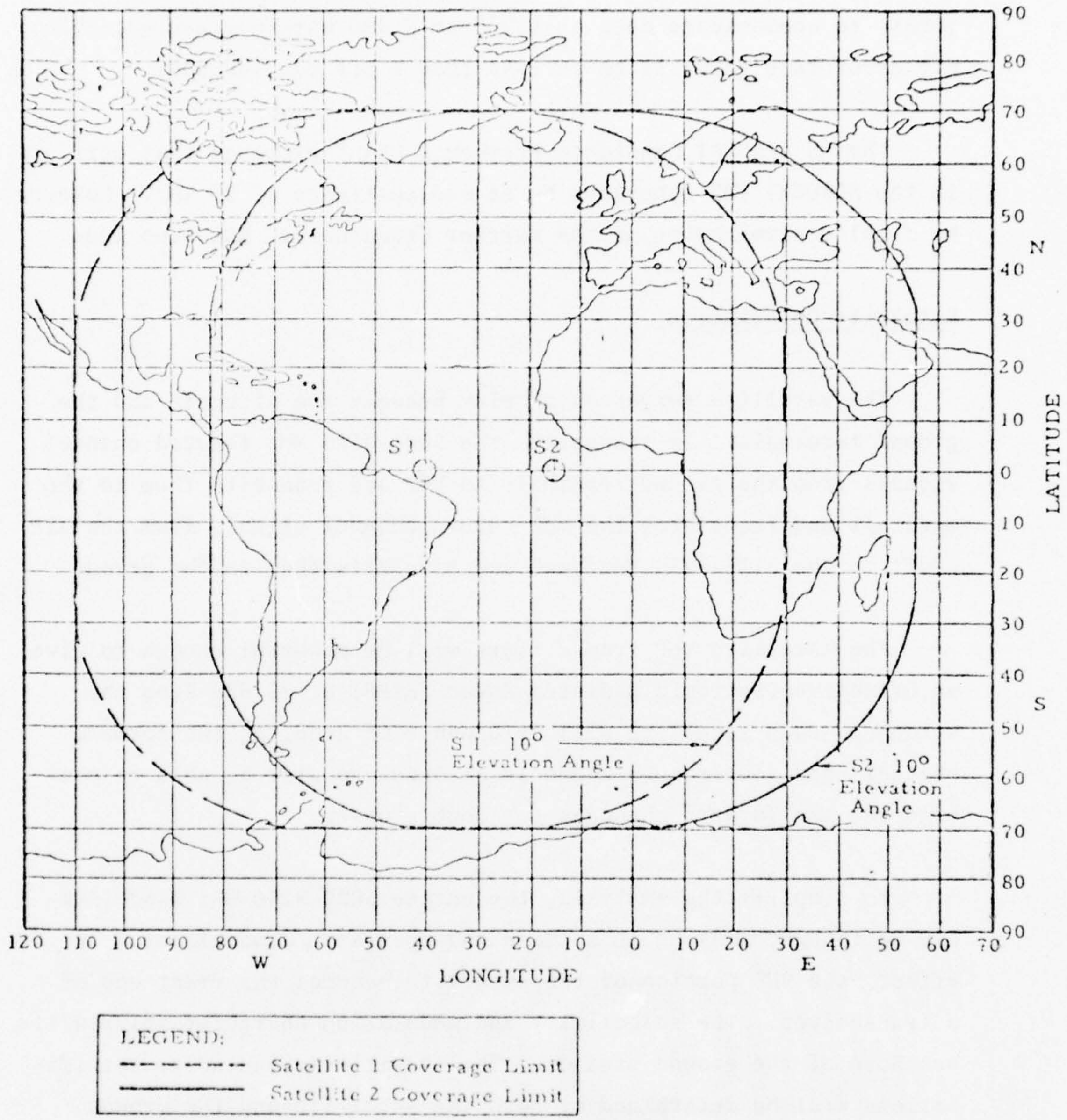

FIGURE 1. ATLANTIC SATELLITE COVERAGE AREAS.

The digital signals will use Differential Phase Shift Keying (DPSK) to communicate data at 1,200 or 2,400 bits per second. The bit error rate (BER) is to be less than 1 bit per 100,000.

The US AEROSAT Candidate Frequency Plan[2] proposes that carriers in the AEROSAT VHF subsystem be at odd multiples of 25 kHz. However, no final determination of the carrier frequencies, has been made.

Satellite Description

The satellite serves as a relay between the aircraft and the ground terminals. It translates the 5000-5125 MHz forward channel signals from the ground terminals to VHF and transmits them to the aircraft and translates the VHF return channel signals from the aircraft to the 5125-5250 MHz band and transmits them to the ground.

The satellite VHF transmitters will be powerful enough to give an Effective Isotropic Radiated Power (EIRP) of 25 dBW from the antenna. Each satellite will be capable of handling two forward channels and four return channels at once and will be able to combine the two forward channels for double power.

To simplify the analysis, the entire 5000-5250 MHz band link can be thought of as an IF section and modulator/demodulator. In effect, the VHF portion of the satellite becomes the front end of a transceiver. The selectivity and modulation characteristics will be those of the ground station. The sensitivity and noise specifications will be determined by both the satellite and the ground station. The RF power and the antenna characteristics will be those of the satellite. This "effective transceiver" will be referred to as the "satellite transceiver." FIGURE 2 is a block diagram depicting the "satellite transceiver."

[2]The Federal Aviation Administration, Candidate Frequency Plan, AEROSAT, US Draft, February 1975.

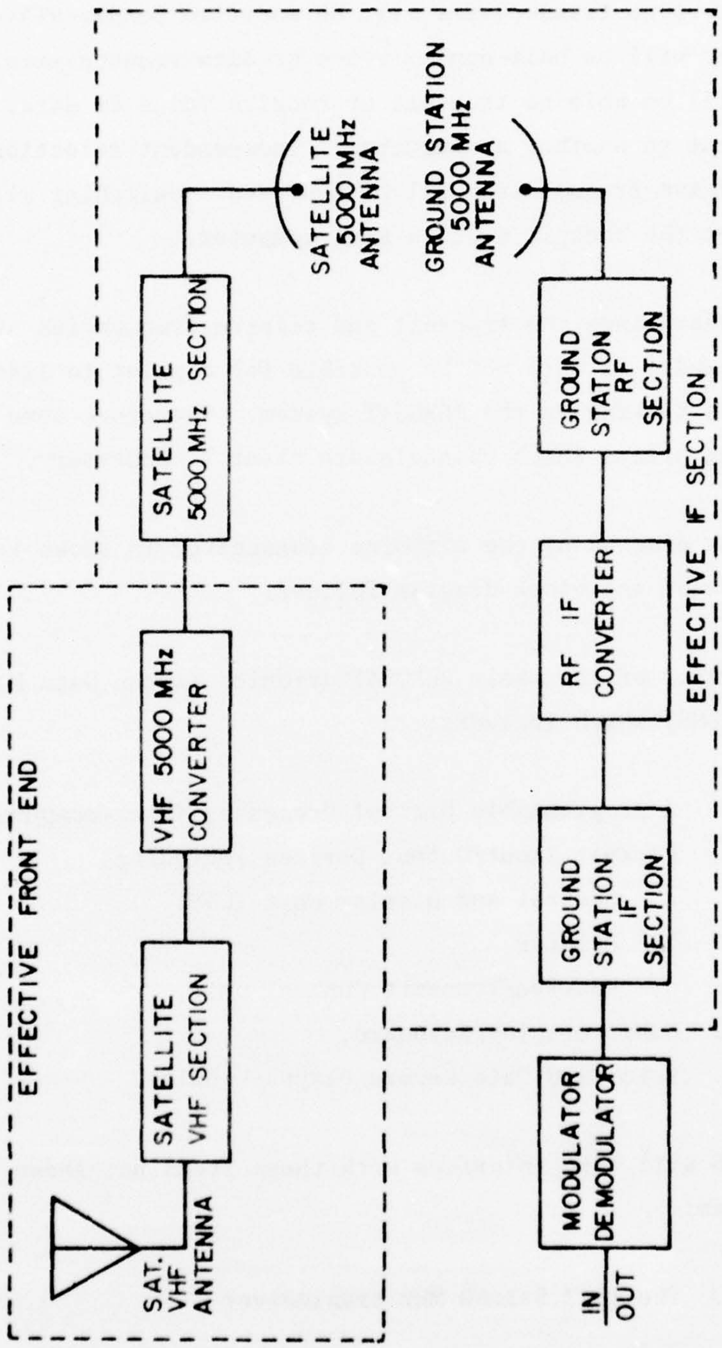

FIGURE 2. EFFECTIVE SATELLITE TRANSCEIVER.

Avionics Description

The airborne transceivers will be modified Bendix RTA-42A[3] units. They will be half-duplex voice or data transceivers; that is, they will be able to transmit or receive voice or data, switching from one mode to another as required. Independent selection of transmit and receive frequencies will be provided. Switching will be controlled from the cockpit or by a mini computer.

Note that since the transmit and receive frequencies are in different bands, it will not be possible for a pilot to listen to other pilots talking on the AEROSAT system. Therefore some method of informing pilots which channels are clear is necessary.

A block diagram of the airborne transceiver is shown in FIGURE 3. A discussion of the block diagram follows.

The center of the whole AEROSAT avionics is the Data Management Subsystem (DMS) which includes:

1. A programmable Digital Processor (Mini-computer),
2. Cockpit Input/Output Devices including;
    a. Control and Display unit (CDU)
    b. Printer
    c. Receive/Transmit Control unit,
3. Cabin Display/Keyboard,
4. Voice and Data Record/Playback units.

The DMS will also interface with these items not shown in the block diagram:

1. The 1543.5-1660 MHz transceiver

[3]*Proposal for an Aeronautical Satellite Communications System*, Bendix Avionics Division, Ft. Lauderdale, FL, April 15, 1973.

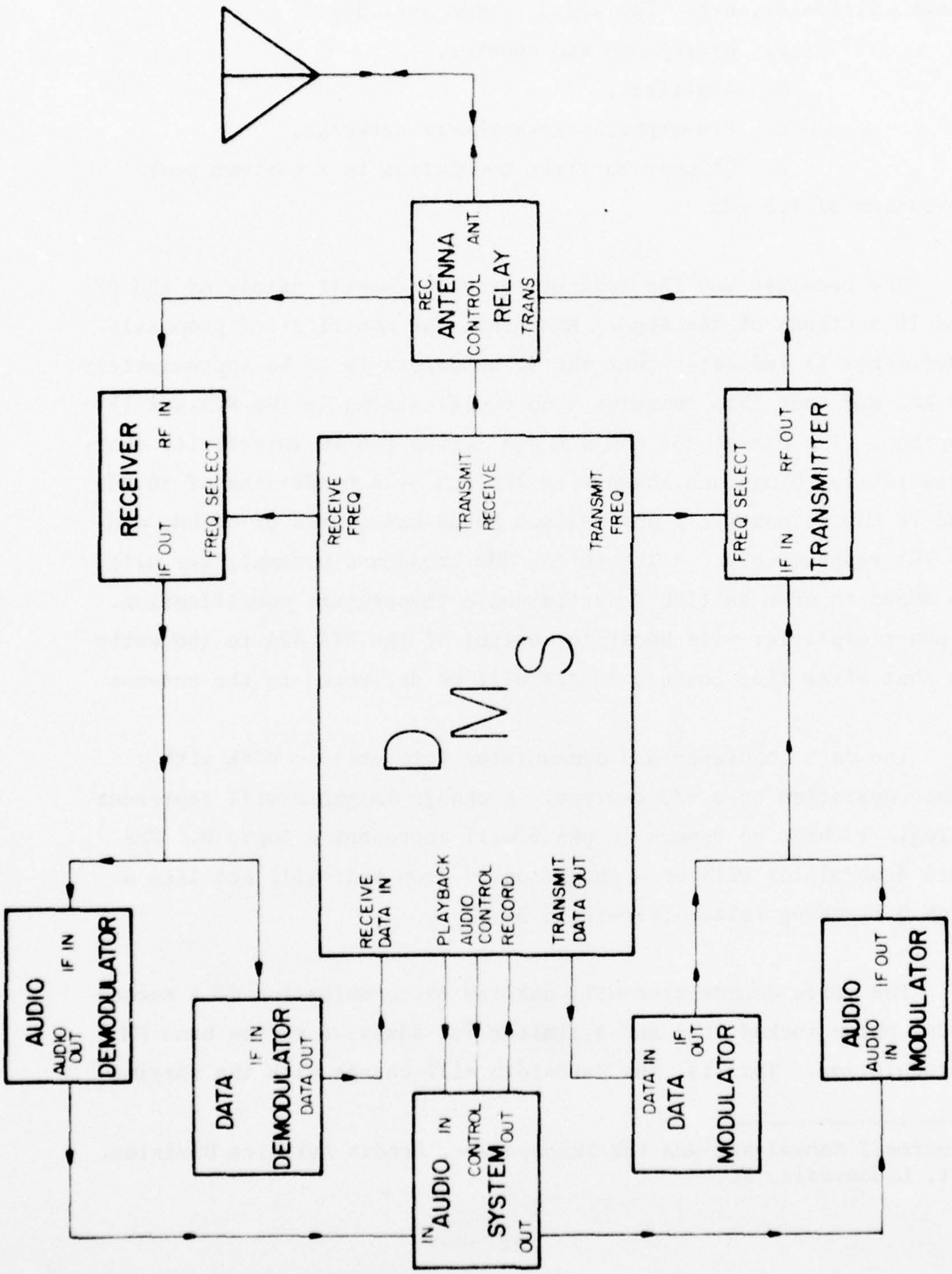

FIGURE 3. BLOCK DIAGRAM OF AEROSAT AVIONICS TRANSCEIVER.

2. Aircraft peripherals such as a Greenwich Mean Time clock, altimeter, etc. The audio system includes:

a. Microphone and speaker,

b. Amplifier,

c. Pre-emphasis/de-emphasis networks,

d. Clipper to limit modulation to a maximum peak deviation of 1.5 kHz.

The receiver and the transmitter will consist mainly of the RF and IF sections of the Bendix RTA-42A. The modification proposals (Reference 3) indicates that the IF bandwidth is to be approximately 20 kHz and that this represents no modifications to the RTA-42A IF section. The manual for the RTA-42A[4] gives two IF selectivity characteristics, broad and sharp with minimum 6-dB bandwidths of 30 kHz and 18 kHz respectively and maximum 60-dB bandwidths of 50 kHz and 39 kHz respectively. A 118 to 136 MHz broadband preamplifier will be added to give an 1100 K system noise temperature specification. A power amplifier will boost the output of the RTA-42A to 150 watts so that after line losses, 19 dBW will be delivered to the antenna.

The data modulator and demodulator will utilize DPSK with a phase deviation of $\pm \pi/2$ radians. A change in phase will represent a logic 1 while no change in phase will represent a logic 0. The data demodulator will be a phase-locked loop that will act like a high Q tracking filter (Reference 3).

The voice demodulator will utilize the combination of a second-order phase locked loop and a limiter for adaptive narrow band FM demodulation. That is, the bandwidth will change with the varying

[4]*Overhaul Manual RTA-42A VHF Transceiver*, Bendix Avionics Division, Ft. Lauderdale, FL.

signal-to-noise ratio (S/N) becoming broader when the S/N is high for greater fidelity and becoming narrower when the S/N is low to reject as much noise as possible.

TERRESTRIAL SYSTEM

The VHF band to be used by AEROSAT is presently being used for air-to-ground communications by commercial and private aircraft. The 125.4 to 126.0 MHz band is being used for Air Traffic Control (ATC) while the 131.4 to 132.0 MHz band is being used for Operational Control (navigation and information). The operational control band is also used by Extended Range VHF stations. These stations, some of which are in the 131.4 to 132.0 MHz band, provide for communication with aircraft out to 400 miles over the ocean. The Extended Range VHF stations are of special importance to this analysis because it is the oceanic areas not covered by Extended Range VHF stations, that AEROSAT must cover. No Extended Range VHF stations are in the 125.4 to 126.0 MHz band.

The terrestrial system uses push-to-talk AM communications where a single channel is used (in a particular area) and everyone in the air and on the ground that is tuned to that frequency is listening to the one person who has switched to transmit and is talking. When two people try to talk at the same time, they interfere with each other.

The channels are 50-kHz wide, centered at multiples of 50 kHz. However by late 1977, many areas will begin converting to 25-kHz wide channels, centered at multiples of 25 kHz. ICAO Annex 10[5] provides the following channel-spacing information for the 117.975-136 MHz band.

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[5]*International Standards and Recommended Practices: Aeronautical Telecommunications Annex 10 to the Convention on International Civil Aviation*, International Civil Aviation Organization, Quebec, Canada, July 1972.

4.1.2.2. After 1 July 1976 and until 1 January 1977, the minimum separation between assignable frequencies in the International Aeronautical Mobile Service shall be 25 kHz in those areas where such channel spacing has been introduced by regional agreement, and the minimum separation between assignable frequencies shall be 50 kHz in all other areas. After 1 January 1977, the minimum separation between assignable frequencies in the International Aeronautical Mobile Service shall be 25 kHz.

NOTE 1 - The intent of this paragraph is to allow those aircraft engaged in operations in areas where 25-kHz channel spacing will not be introduced prior to 1 January 1977 an additional period of time in which to effect the required airborne equipment modifications necessary to operate in a 25-kHz channel spacing environment.

NOTE 2 - It is recognized that, after 1 July 1976 and even after 1 January 1977 in some regions or areas, 100-kHz or 50-kHz channel spacing may provide an adequate number of frequencies suitably related to international and national air services and that equipment designed specifically for 100-kHz or 50-kHz channel spacing will remain adequate for services operating within such regions or areas.

Ground receivers operating within the 117.975-136 MHz band will be required to reject adjacent channels in accordance with the following (Reference 5).

4.6.2.3. Adjacent channel rejection. The receiving system shall ensure an effective rejection of 60 dB or more at the next assignable channel.

NOTE - The next assignable frequency will normally be plus or minus 50 kHz. Where this channel spacing will not suffice, the next assignable frequency will be plus or minus 25 kHz implemented in accordance with the provisions of Part II, 4.1.2. It is recognized that in certain areas of the world receivers designed for 50-kHz or 100-kHz channel spacing may continue to be used.

Also, airborne receivers operating in the 117.975-136 MHz will be required to reject adjacent channels (Reference 5).

4.7.2.3. Adjacent channel rejection. The receiving function shall ensure an effective adjacent channel rejection as follows:

a. 25-kHz channel spacing environment: 50 dB or more at plus or minus 25 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 17 kHz;
b. 50-kHz channel spacing environment: 50 dB or more at plus or minus 50 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 35 kHz;
c. 100-kHz channel spacing environment: 50 dB or more at plus or minus 100 kHz with respect to the assigned frequency;

4.7.2.4. RECOMMENDATION - Whenever practicable, the receiving system should ensure an effective adjacent channel rejection characteristic of 60 dB or more at

> plus or minus 25 kHz, 50 kHz and 100 kHz from the assigned frequency for receiving systems intended to operate in channel spacing environments of 25 kHz, 50 kHz and 100 kHz respectively.

The Federal Communications Commission has provided for the conversion of the 117.975-136 MHz band to 25-kHz spacing. The FCC Rules and Regulations have been changed to reflect this change, as discussed by FCC in the following paragraph.[6]

> 23. In summary, we are amending the rules to provide for a virtual doubling of the frequencies in the aeronautical mobile (R) band 117.975-136 MHz by providing for 25-kHz channel spacing. We are changing the frequency tolerances of both new ground transmitting and new airborne transmitting equipment to 0.002 and 0.003 percent respectively. The emission 13A9 will be authorized throughout the operational control band. We are establishing a cut-off date (1-1-74) for the type acceptance of new ground and airborne transmitters but not for the utilization of existing equipment. We are leaving this docket open pending the finalization of FAA's implementation plan and of proven evidence that continued use of 50-kHz configured equipment in the system causes unacceptable interference to the aeronautical community. We are providing the 25-kHz frequencies and the new tolerances to make it possible for manufacturers, station operators and users to proceed with the improvement of the system. We are providing for amendments which will allow better coordination and fuller usage of the flight test frequencies. In our opinion these amendments will allow for an assist in improvements to the existing aeronautical mobile (R) service in a manner most suitable to

[6] Federal Communication Commission Report and Order Regarding Aeronautical Mobile (R) VHF Band, Federal Register, October 19, 1973.

the early needs of air carriers to modify the offset carrier system, the financial needs of general aviation for adequate amortization time, and the FAA's implementation of the air space above 18,000 feet. Lacking a definitive FAA implementation program it would be unreasonable for the Commission to impose cut-off dates on aircraft operators which quite conceivably, would result in a considerable expenditure for new equipment of no improved value for lack of improved ground equipment with which to communicate.

The paragraphs quoted above indicate that conversion to equipment with 25-kHz selectivity is not mandatory at any specific future time in the US, and that conversion is required by ICAO only in certain unspecified areas of the world. However, information[7] has been provided to ECAC indicating that Canadian commercial aircraft will be converted to the 25-kHz selectivity in accordance with the ICAO schedule, i.e., not later than January 1, 1977. Information[8] provided to ECAC by ARINC indicates that, in the US, nearly all commercial aircraft are expected to be converted to 25-kHz selectivity not later than August 1977. Most ARINC ground stations in the 131.4-132 MHz band have been converted to 25-kHz selectivity at the present time; conversion of all stations in this band is expected to be complete by January 1977.

[7]TELCONS between J. Preis, ECAC, Ted Page, FAA, and Wayne Longman, Canadian Ministry of Transport, Ottawa, August 4, 1975.

[8]TELCONS between J. Preis, ECAC and R. Sollien, ARINC, July 8, 1975 and October 9, 1975.

The airborne transceivers are ARINC characteristic 546,[9] 566,[10] and 566A[11] units. They transmit a 6A3 modulated 25-50 watt carrier at an exact multiple of 50 kHz, or 25 kHz ± 6 kHz, or ± 4 kHz stability respectively. They can receive 6A3 modulated signals above -133.5 dBW (133.5 dB below 1 watt) offset by as much as 8 kHz from an even multiple of 50 kHz (or 25 kHz).

The ground transceivers are similar to the airborne transceivers except:

1. Transmitter power varies from 5 watts to 1000 watts.

2. The transmitted carrier frequency may be offset by as much as 8 kHz from an exact multiple of 50 kHz (or 25 kHz). In the operational control band in the US, offsets up to 8 kHz are used. No offsets are used in the 125.4 to 126.0 MHz band in the US and Canada except in Alaska. In areas where offsets are used the stability is assumed to be 0 kHz.

3. In areas where offsets are not used the stability is ± 6 kHz for 50-kHz channels ± 3 kHz for 25-kHz channels.

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[9]*Airborne VHF Communications Transceiver System*, ARINC Characteristic No. 546, Aeronautical Radio, Inc., October 1961.

[10]*Airborne VHF Communications Transceiver and Mark 1 VHF SATCOM Systems*, ARINC Characteristic No. 566, Aeronautical Radio, Inc., October 17, 1968.

[11]*Mark 3 VHF Communications Transceiver*, ARINC Characteristic No. 566A, Aeronautical Radio, Inc., August 23, 1972.

SECTION 3

ANALYSIS

POTENTIAL INTERFERENCE SITUATIONS

There are 7 potential interference situations. FIGURES 4 through 6 show the situations where the terrestrial system potentially interferes with the AEROSAT system. FIGURES 7 through 10 show the situations where the AEROSAT system potentially interferes with the terrestrial system. In all 7 figures, a desired signal path is designated with a D and an undesired signal path is designated with a U.

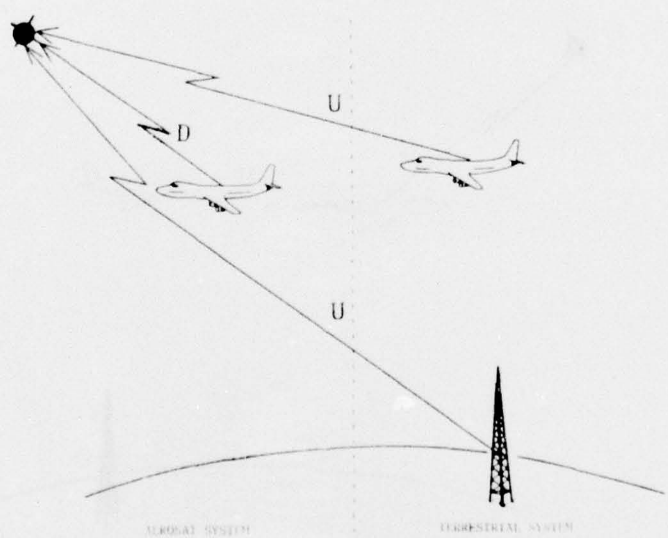


FIGURE 4. TERRESTRIAL SYSTEM POTENTIAL INTERFERENCE TO THE SATELLITE RECEIVER.

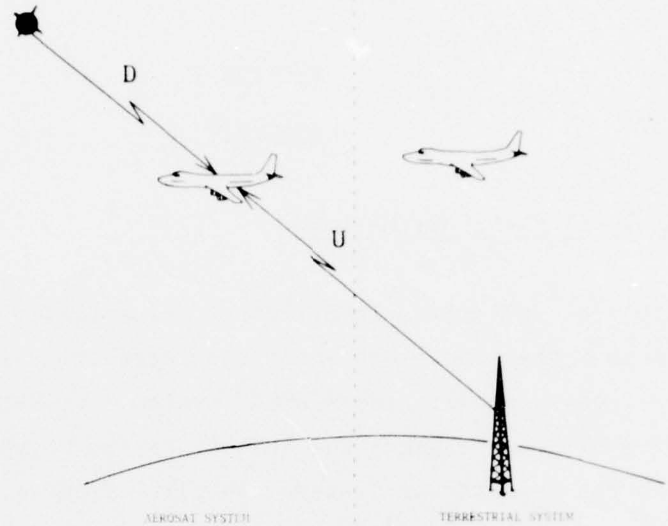


FIGURE 5. TERRESTRIAL SYSTEM GROUND TRANSMITTER POTENTIAL INTERFERENCE TO THE AEROSAT AVIONICS RECEIVER.

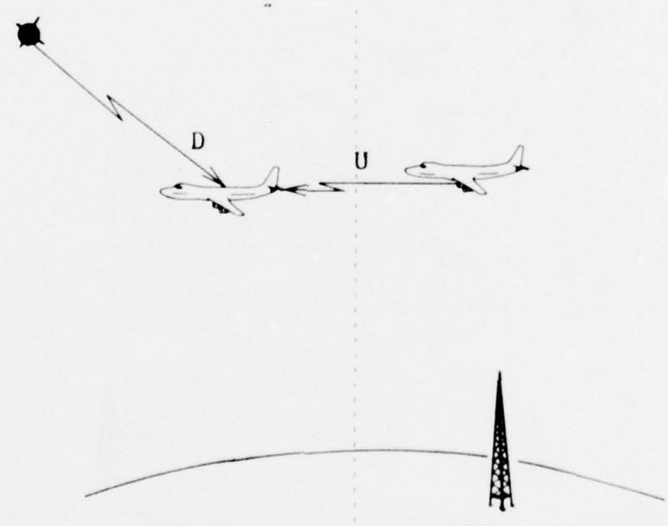


FIGURE 6. TERRESTRIAL SYSTEM AIRBORNE TRANSMITTER POTENTIAL INTERFERENCE TO THE AEROSAT AVIONICS RECEIVER.

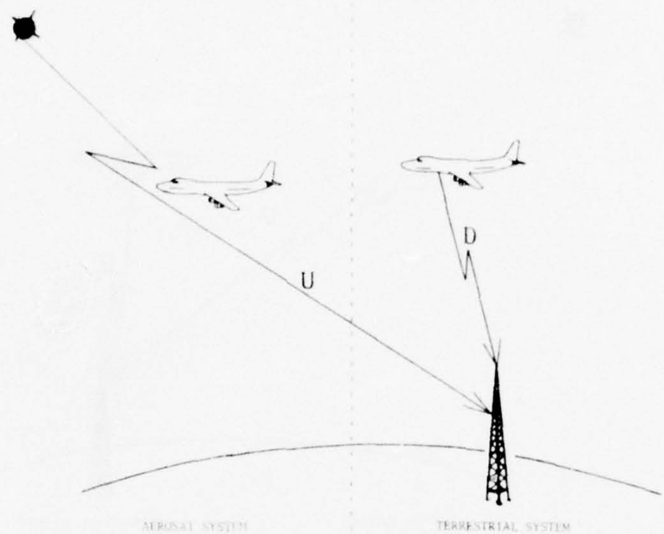


FIGURE 7. AEROSAT SATELLITE TRANSMITTER POTENTIAL INTERFERENCE TO THE TERRESTRIAL SYSTEM GROUND RECEIVER.

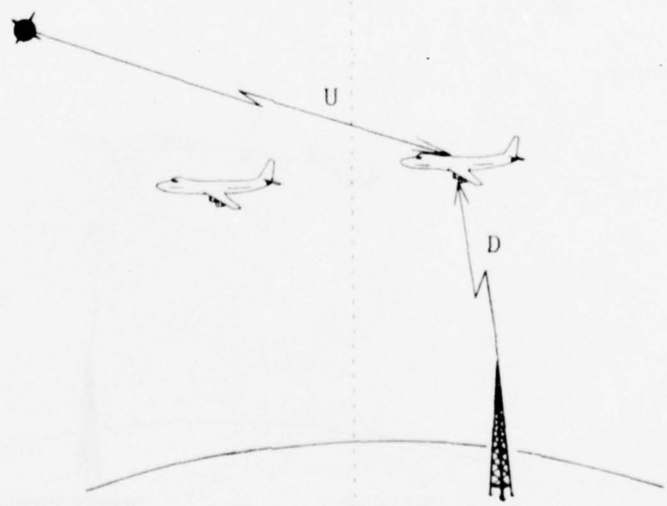


FIGURE 8. AEROSAT SATELLITE TRANSMITTER POTENTIAL INTERFERENCE TO THE TERRESTRIAL SYSTEM AIRBORNE RECEIVER.

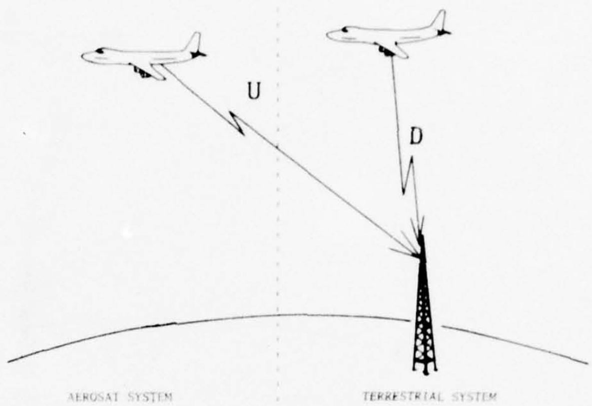


FIGURE 9. AEROSAT AIRBORNE TRANSMITTER POTENTIAL INTERFERENCE TO THE TERRESTRIAL SYSTEM GROUND RECEIVER.

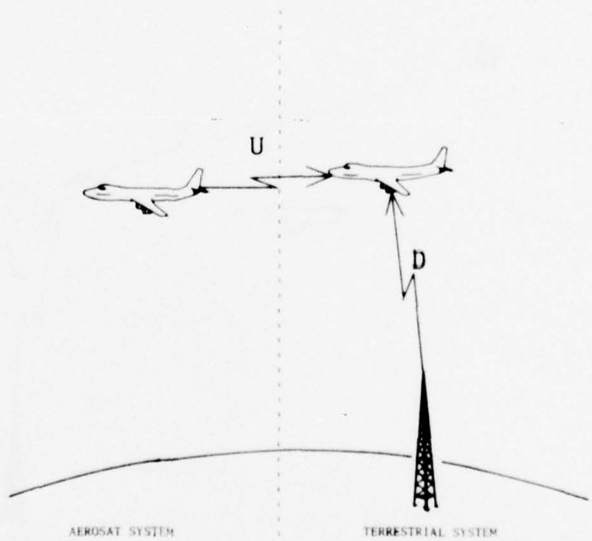


FIGURE 10. AEROSAT AIRBORNE TRANSMITTER POTENTIAL INTERFERENCE TO THE TERRESTRIAL SYSTEM AIRBORNE RECEIVER.

ANALYSIS PARAMETERS

General

This section provides the mathematical development of the factors (such as interference thresholds and propagation factors) used in the interference calculations.

Antennas and Transmission Lines

All antennas in the terrestrial system are vertically polarized and designed to be omni-directional (except for special cases which will be noted). The ground antennas have some gain which is assumed to be balanced by line losses. The terrestrial system airborne antennas have 0-dBi gain and the transmission line loss is assumed to be 1 dB.

All antennas in the AEROSAT system will be left-hand circularly polarized. The satellite antenna will have a gain of 10 dBi over the entire area of coverage. For the airborne antenna, AEROSAT will use the BOEING 747 SATCOM Antenna. This antenna is designed to give maximum gain for LH circularly polarized signals in all directions with an elevation of 10° or more (the gain is -2 dBi to +5 dBi over that region) and minimum gain elsewhere. The transmission line losses and transmitter powers are such that 19 dBW is delivered to the airborne antenna and 15 dBW is delivered to the satellite antenna.

For calculating interference between the AEROSAT system and the terrestrial system, the vertical polarization characteristics of the BOEING antenna are needed. FIGURES 11 and 12 give the upper and lower bounds of measured antenna voltage gain for all types of linear polarization. It is impossible to determine where between the upper and lower

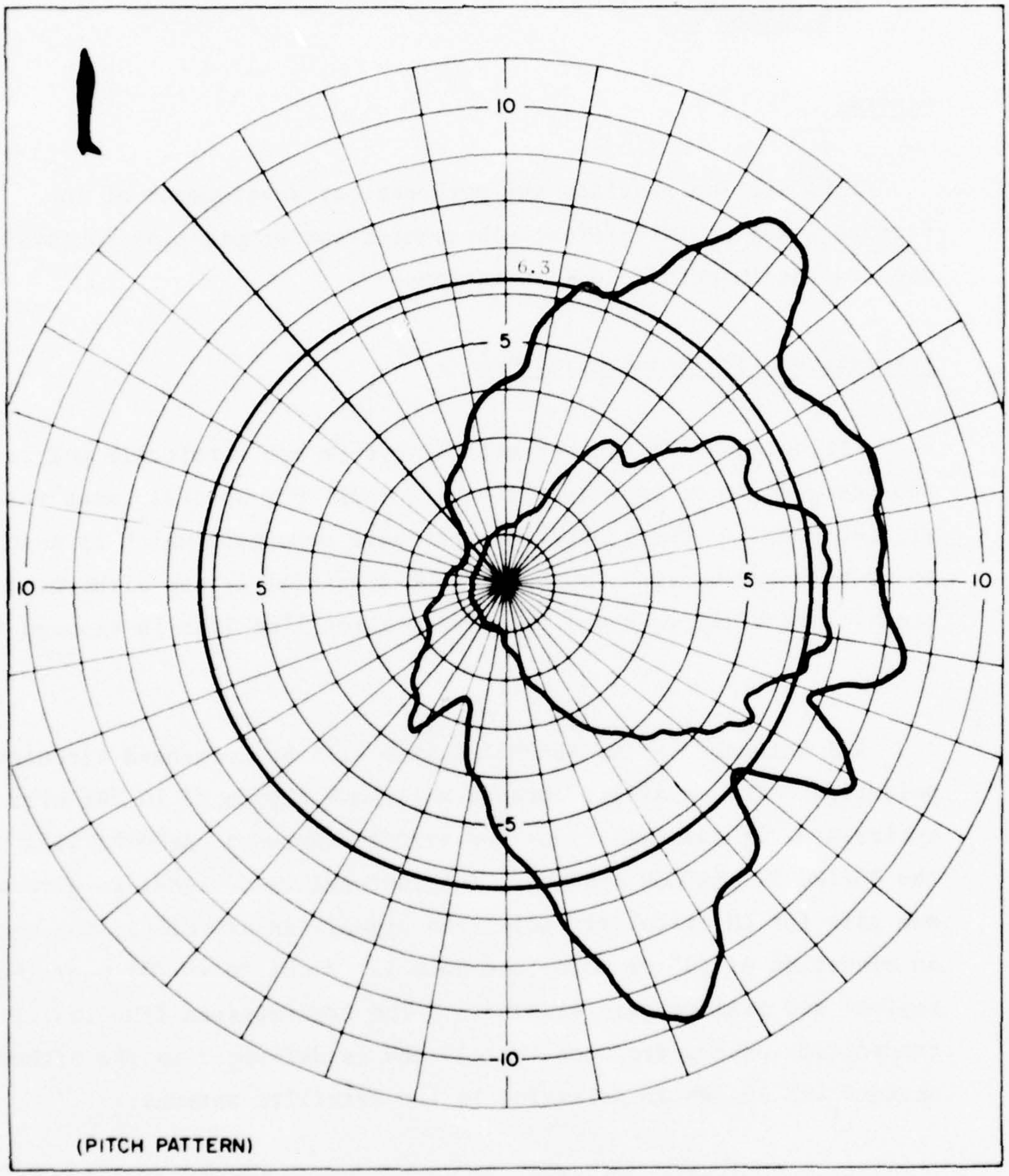


FIGURE 11. BOEING 747 SATCOM ANTENNA VOLTAGE PATTERN FOR LINEAR POLARIZATION (PITCH PATTERN).

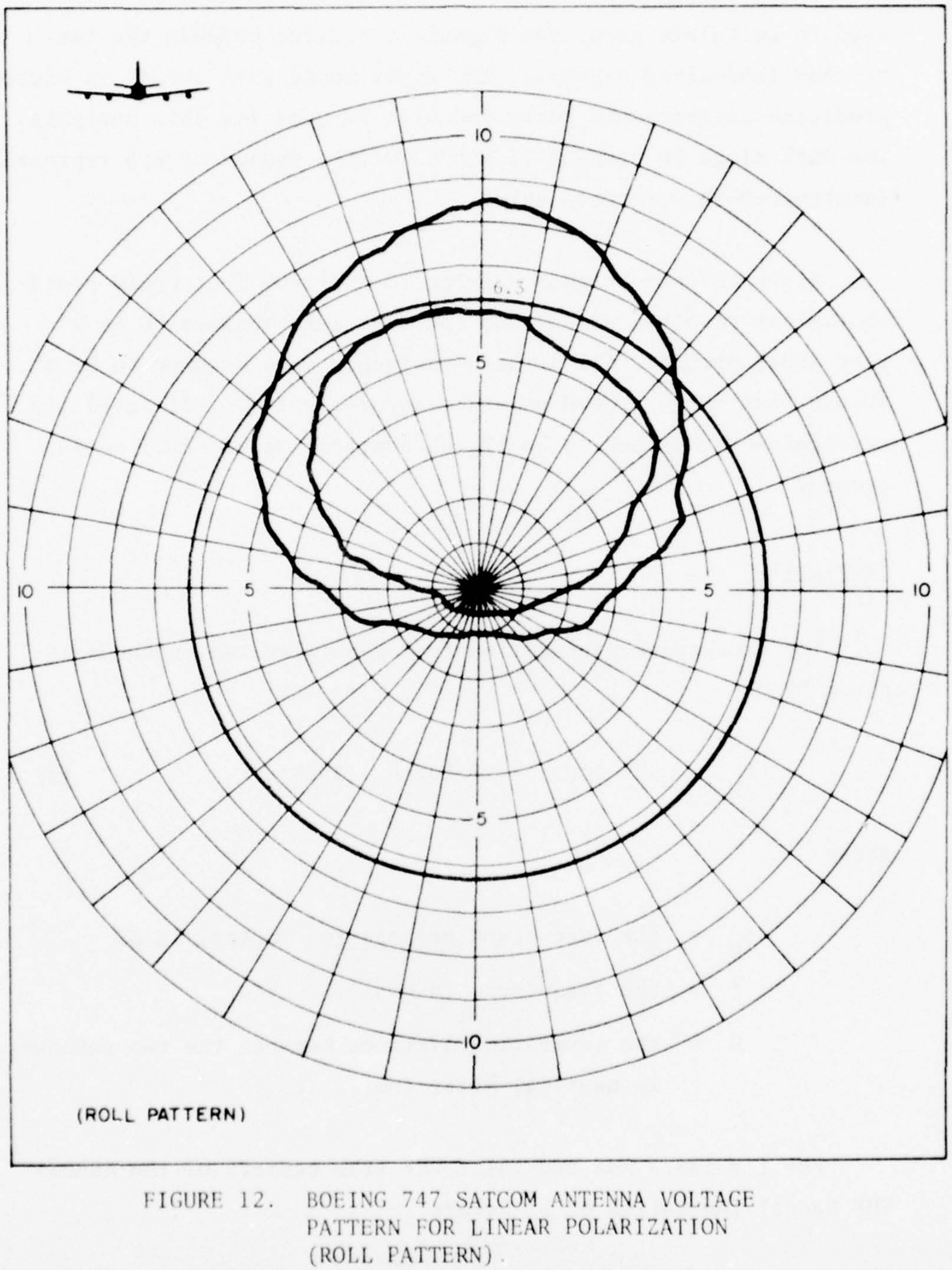


FIGURE 12. BOEING 747 SATCOM ANTENNA VOLTAGE PATTERN FOR LINEAR POLARIZATION (ROLL PATTERN).

bounds the vertical polarization pattern would be. Since the vertical polarization pattern for the Boeing antenna is only used to calculate gains for signals traveling between the two systems (undesired signals), the upper bound will result in higher predicted interference power and will be used for this analysis. The dark rings in FIGURES 11 and 12 with a radius of 6.3 represent isotropic 0-dB reference gain.

Since antenna heights between 10 and 1000 feet would yield equivalent results, all ground antennas were assumed to be 50 feet above ground. All airborne antennas were assumed to be at 40,000 feet above ground unless otherwise noted. All satellite antennas were assumed to be 19,400 nautical miles (nmi) above ground.

Propagation

The free-space propagation factor between two antennas is given by:

$$L_p = -20 \log f - 20 \log D - 37.8 \qquad (1)$$

where

L_p = the free-space propagation factor, in dB

f = the frequency, in MHz

D = the separation distance between the two antennas, in nautical miles (nmi).

For f = 125.7 MHz and 131.7 MHz (the centers of the AEROSAT VHF bands) the values of L_p become:

L_p at 125.7 MHz = -79.8 - 20 log D

L_p at 131.7 MHz = -80.2 - 20 log D.

For communication with a geostationary satellite, the distance D varies from 19,400 nmi to 22,000 nmi depending on the satellite elevation angle. Therefore L_p becomes:

L_p satellite-to-earth (125.7 MHz) = -165.6 dB to -166.6 dB

L_p earth-to-satellite (131.7 MHz) = -166.0 dB to -167.0 dB.

Ionospheric Effects

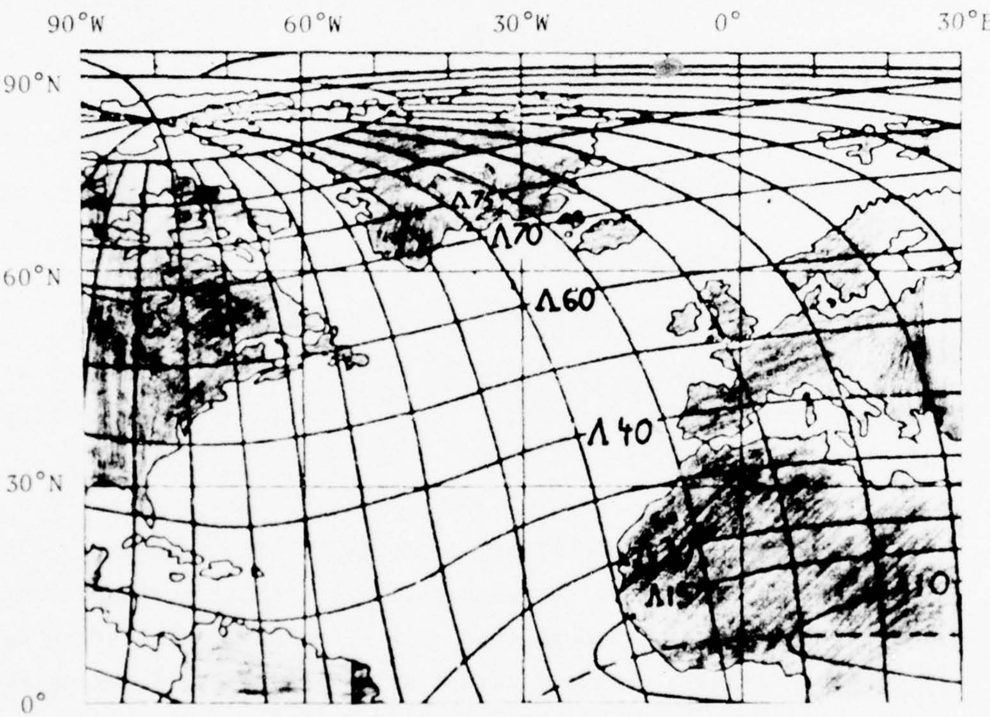
The ionosphere is a plasma of free electrons and nuclei with a magnetic field. The refractive index of a plasma is a function of the charge density.[12]

This charge density is not a constant. The ionosphere contains many "clouds" of higher charge density that cause perturbations in the signals passing through them. These clouds, which often reach a length of several hundred yards, act like lenses, focusing the waves on certain regions while shading other regions. The exact effects these clouds have depends on their shape, size, number, and the magnetic field present. Due to the different refractive indices encountered, waves may be delayed at times causing unusual phase effects.

These perturbations are called scintillations. The frequencies of the scintillations range from one cycle per second to two minutes per cycle. The magnitude varies depending on location and time of

[12] Stratton, J. A., *Electromagnetic Theory*, McGraw-Hill, New York, 1941.

day. Scintillation is usually worst around midnight. Since scintillation is a function of magnetic field, it is not surprising that scintillation intensity is dependent on invariant geomagnetic latitude. Invariant geomagnetic coordinates are a function of the magnetic poles and are shown in FIGURE 13.



Λ denotes invariant geomagnetic latitude.

FIGURE 13. MAP WITH INVARIANT GEOMAGNETIC COORDINATES.

There are five scintillation regions. The VHF scintillation levels in the five regions are given in TABLE 1. The presently available measured data displays large variations. Therefore, only approximate values can be assigned at this time for consideration in this analysis.

TABLE 1

VHF SCINTILLATION LEVELS (APPROXIMATE)

Region	Latitudes	Signal Level Relative to the Median Exceeded 1% of the Time	Signal Level Relative to the Median Exceeded 99% of the Time
Polar	75° - 90°	5 dB	- 4 dB
Irregularity	60° - 75°	6 dB	- 5 dB
Boundary	50° - 60°	3 dB	- 2 dB
Mid-Latitudes	15° - 50°	<.5 dB	>-.5 dB
Equatorial	0° - 15°	.5 dB	- 4 dB

FIGURE 14 shows continuous curves that approximate the data in TABLE 1.

A more complete discussion of scintillation may be found in the literature[13,14] from which the information used in the preceeding discussion was obtained.

Multipath

In addition to the line-of-sight path between transmitter and receiver, the signal may simultaneously travel along a second path that reflects off of the earth's surface as shown in FIGURE 15.

This phenomenon is called multipath. Since the two paths do not have the same length, the signals may not be in phase. Depending on the phase, the reflected wave may reinforce or cancel the direct wave.

[13] Giordano, J. A., *Ionospheric Scintillations*, MTR-6559, Mitre Corporation, December 3, 1973.

[14] Elkins, T. J., and Slack, F. F., *Observations of Traveling Ionospheric Disturbances Using Stationary Satellites*, Journal of Atmospheric and Terrestrial Physics 1969, Vol. 31, pp. 431-439.

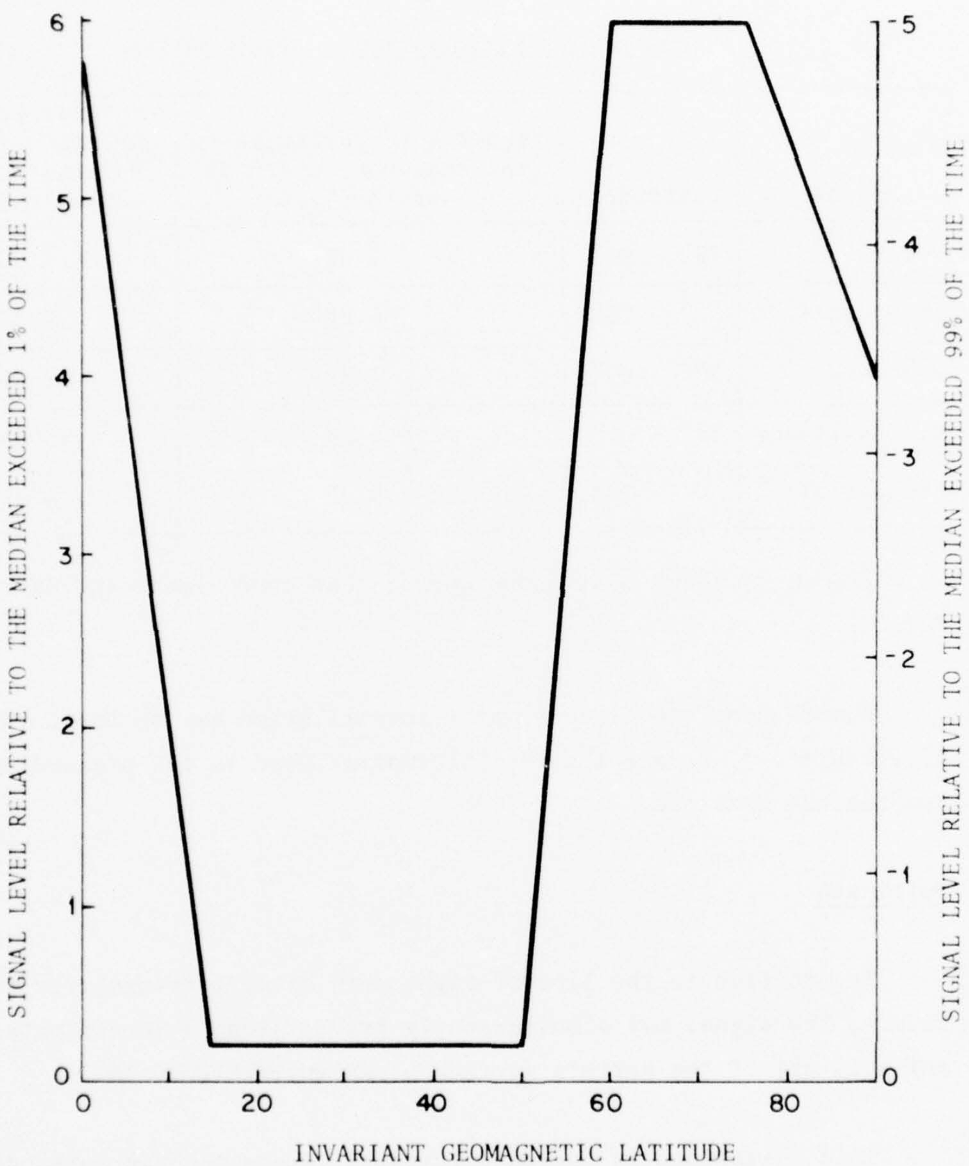


FIGURE 14. SCINTILLATION LEVELS.

To model multipath, what happens when the signal reflects off the earth's surface needs to be known. This is described by the reflection coefficient (R) of the earth's surface and by the divergence factor (Df) due to the curvature of the earth. The divergence factor is given by:

$$Df = \left[1 + \frac{2\, r_1 r_2}{a\,(r_1 + r_2)\,\sin\theta}\right]^{-\frac{1}{2}} \qquad (2)$$

where

Df = the divergence factor

r_1 = the distance from the transmitter to the point of reflection

r_2 = the distance from the receiver to the point of reflection

θ = the angle between the ray and the reflecting surface (grazing angle)

a = the radius of curvature of the surface.

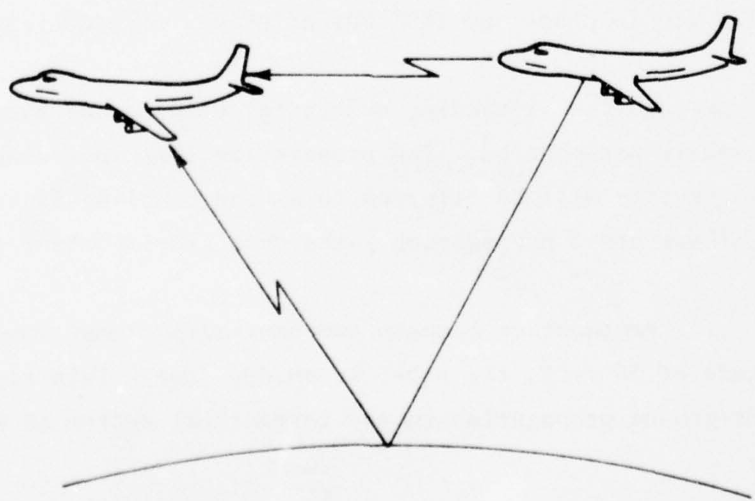


FIGURE 15. MULTIPATH DIAGRAM.

Due to the high reflection coefficient of saltwater, maximum multipath effects occur when the reflecting surface is sea water. The reflection coefficient for sea water at 130 MHz is given in FIGURE 16. The upper curve (R_H) represents the magnitude of the reflection coefficient for horizontally polarized signals. The lower curve (R_V) represents the magnitude of the reflection coefficient for vertically polarized signals.

The magnitude of the reflected field at the receiver is given by:

$$|\vec{Er}| = RDf|\vec{Ei}| \tag{3}$$

where

$|\vec{Er}|$ = the magnitude of the reflected field

$|\vec{Ei}|$ = the magnitude the field would have had if it had traveled the same path but reflected off a flat, perfectly reflecting surface.

The field at the receiver is the algebraic sum of the direct path field and the reflected field. Maximums and minimums occur when the fields are in phase and 180° out of phase, respectively.

The propagation (including multipath) between two antennas below the ionosphere was modeled. The propagation loss including antenna and multipath factors will be referred to as the coupling factor in this report. There are 3 propagation paths that are important to this analysis:

1. *Propagation between two omni-directional antennas, one at an altitude of 50 feet, the other at 40,000 feet.* This represents desired air-ground propagation in the terrestrial system as shown in

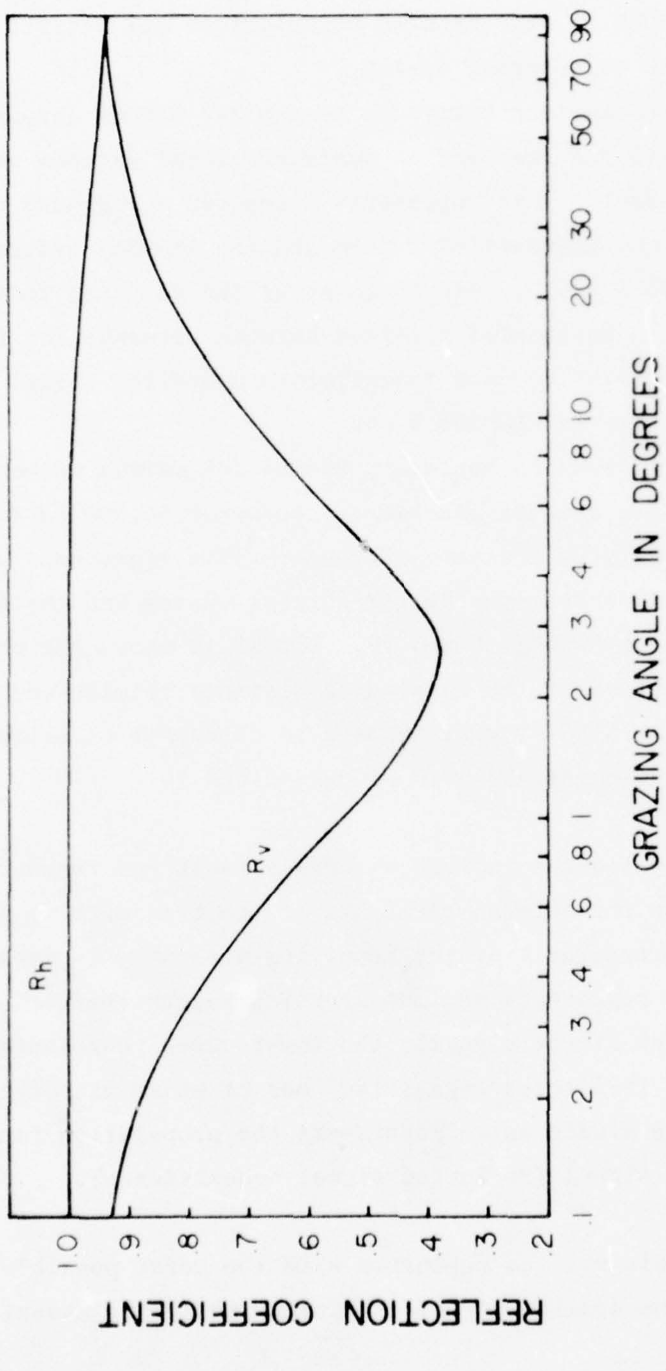


FIGURE 16. REFLECTION COEFFICIENT OF SEA WATER AT 130 MHz.

FIGURES 7, 8, 9, and 10. FIGURE 17 shows the coupling factor (CF) as a function of the horizontal distance between the antennas for this case. FIGURE 17 will be used to calculate all desired signal strengths in the terrestrial system.

2. *Propagation between a Boeing 747 SATCOM antenna at an altitude of 40,000 feet and an omnidirectional antenna at an altitude of 50 feet.* This represents undesired air-ground propagation between the terrestrial system and the AEROSAT system as shown in FIGURES 5 and 9. FIGURE 18 shows the coupling factor as a function of the horizontal distance between antennas for this case. FIGURE 18 will be used to calculate undesired signal strengths for the cases shown in FIGURES 5 and 9.

3. *Propagation between a Boeing 747 SATCOM antenna and an omnidirectional antenna both at altitudes of 30,000 to 40,000 feet but not necessarily at the same altitude.* This represents undesired air-air propagation between the terrestrial system and the AEROSAT system as shown in FIGURES 6 and 10. FIGURE 19 shows the coupling factor as a function of the horizontal distance between the antennas for this case. FIGURE 19 will be used to calculate undesired signal strengths for the cases shown in FIGURES 6 and 10.

These three figures include antenna effects and represent the coupling between the antenna terminals of the transmitting antenna and the antenna terminals of the receiving antenna. In each figure, the upper curve represents maximum signal strength (reflected signal in phase with the direct signal), the lower curve represents minimum signal strength (reflected signal 180° out of phase with the direct signal), and the middle curve represents the propagation factor for the direct path signal (reflected signal nonexistence).

This analysis will be concerned with the worst possible interference where the desired signal is minimum while the undesired signal

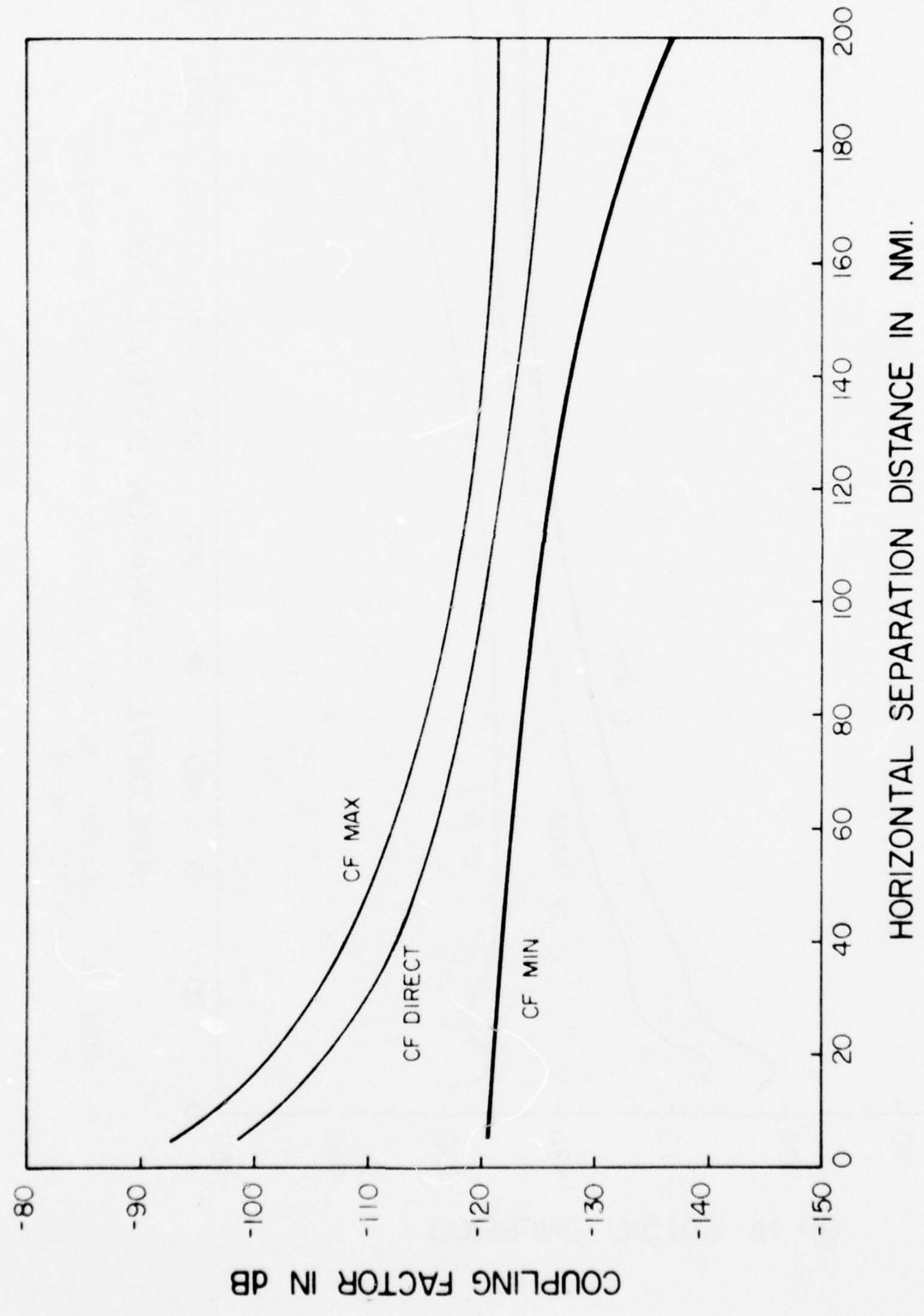


FIGURE 17. AIR-GROUND PROPAGATION IN THE TERRESTRIAL SYSTEM.

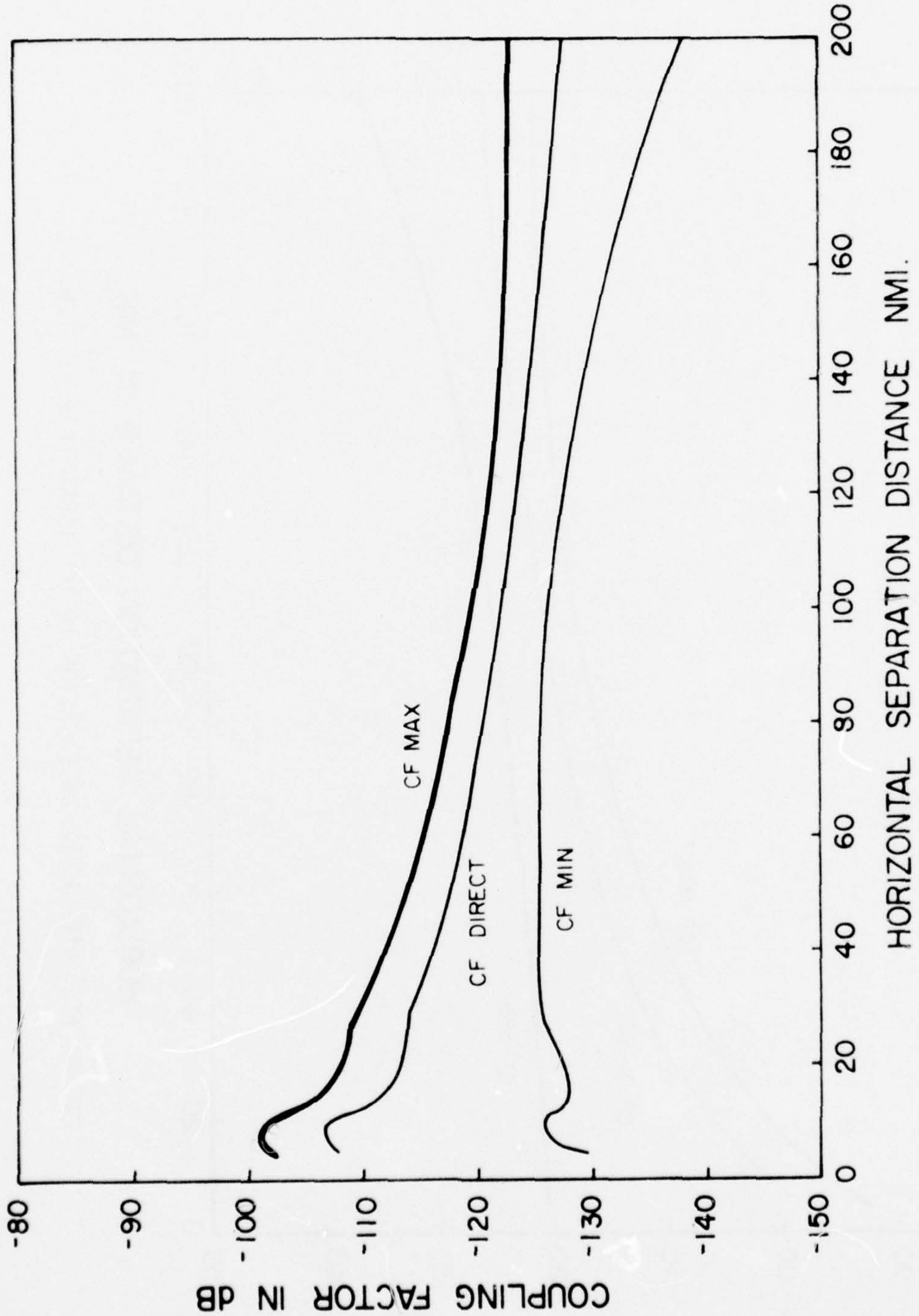


FIGURE 18. PROPAGATION BETWEEN AN AEROSAT AIRPLANE AND A TERRESTRIAL SYSTEM GROUND STATION.

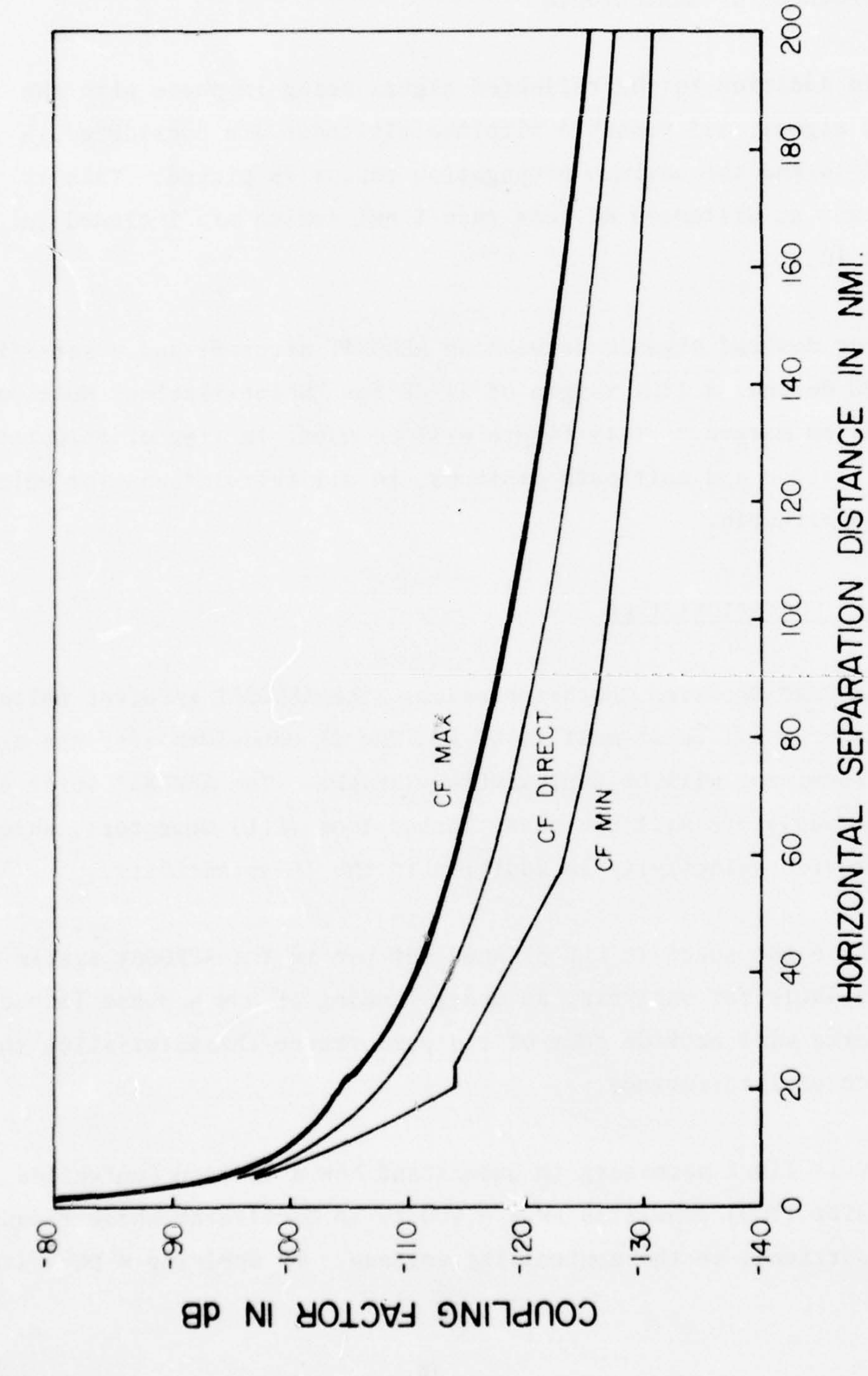


FIGURE 19. PROPAGATION BETWEEN AN AEROSAT AIRPLANE AND A TERRESTRIAL SYSTEM AIRPLANE.

is maximum. Therefore the lower curve in FIGURE 17 and the upper curves in FIGURES 18 and 19 are of primary interest. These curves are darkened for convenience.

In addition to the reflected signal being in phase with the direct signal, all possible airplane altitudes are considered in FIGURE 18 and the maximum propagation factor is picked. This is important at distances of less than 5 nmi (which are included in FIGURE 19).

For desired signals between an AEROSAT aircraft and a satellite, the MOU defines a link margin of 11 dB for "Scintillation, Multipath, and System Margin." This figure will be used, in lieu of calculating scintillation and multipath minimums, in all calculations for which it is applicable.

Receiver Characteristics

AEROSAT Receiver Characteristics. The AEROSAT receiver noise temperature will be at most 1,100 K. The IF bandwidth (for the airborne receiver) will be approximately 20 kHz. The AEROSAT voice and data demodulators will use phase locked loop (PLL) detectors, which will provide selectivity in addition to the IF selectivity.

While the specific PLL planned for use in the AEROSAT system was not available for analysis, an understanding of how a phase locked loop works will provide some of its performance characteristics in the presence of interference.

It is first necessary to understand how a Voltage Controlled Oscillator (VCO) generates FM. A VCO is an oscillator whose frequency is proportional to the controlling voltage. By applying a DC voltage

to the VCO, a constant frequency "carrier" output is obtained. By superimposing an audio signal on the DC input voltage to the VCO, a frequency modulated carrier output is obtained. A VCO is essentially an FM modulator.

A typical PLL is diagrammed in FIGURE 20. The output of the VCO is compared to the PLL input signal be a phase detector. The output of the phase detector is "fed back" into the VCO through a filter. The PLL locks on to the input signal and the output of the VCO equals the PLL input signal. In effect the VCO is mimicking the transmitter that originally transmitted the signal. Therefore the input to the VCO must also mimic the input to the transmitter that originally transmitted the signal. This signal is the output of the PLL.

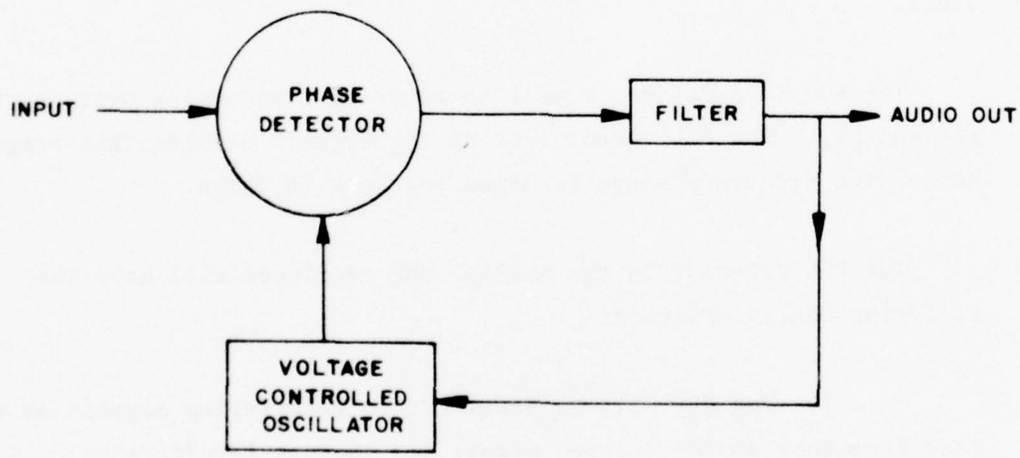


FIGURE 20. PHASE LOCKED LOOP DETECTOR.

The filter is an audio filter, but because of its location in the detector, it acts like an IF filter. The VCO and phase detector act like an oscillator-mixer with an output IF center frequency of zero Hz. For example if the filter is a low pass filter with a 3-dB

point of 3 kHz, it would act like an IF filter that attenuates signals, 3-kHz off tune, 3 dB (i.e. a 3-dB IF bandwidth of 6 kHz). Very high selectivity is possible with a phase locked loop, but being a feedback system, the higher order filters necessary for high selectivity cause stability problems. The filter in the AEROSAT VHF receiver will have a transfer function like (Reference 3):

$$\frac{T\,s + 1}{s} \tag{4}$$

where

s = complex frequency

T = a constant.

A PLL with a filter with the above transfer function is "second order."

The VCO in a PLL has a maximum range of frequencies over which it can vary. The PLL cannot lock on the signals outside this range, hence, the frequency range is named the lock-in range.

The PLL detector in the AEROSAT VHF receivers will have the following characteristics:

1. The PLL will be sensitive to interfering signals at the same frequency as the desired signal (co-channel interference). A co-channel undesired signal at the same level as the desired signal will cause consistent loss of lock and therefore makes communication impossible.[15]

2. An interfering signal that is not co-channel but is inside the lock in range will be capable of pulling the PLL away from

[15] Britt, C. V. and Palmer, D. F., *Effects of CW Interference on Narrow-Band Second-Order Phase Lock Loops*, Research Triangle Institute, Research Triangle, NC, July 27, 1966.

the desired signal so that the PLL locks on to the undesired signal. It is not known how strong an undesired signal is necessary to make the PLL switch lock.

3. An interfering signal that is outside the lock in range will not break the lock of the PLL but may still cause some distortion.

Loss of lock is the most serious degradation a PLL can suffer. If a PLL is not locked on to a signal, it is not demodulating that signal.

The AEROSAT data demodulator will be a PLL with characteristics similar to the voice demodulator.

Terrestrial System Receiver Characteristics. An airborne receiver in the terrestrial system is the receiver part of an ARINC characteristic 546, 566, or 566A transceiver (References 9, 10, and 11). The sensitivity is such that a carrier with a power of -133.5 dBW, with a 1,000-Hz tone modulating it 30% applied to the antenna terminals will give a signal-to-noise ratio (S/N) at the speaker terminals of 4.74 dB. [(S + N)/N = 6 dB]

The 546 and 566 characteristic transceivers each have two different IF selectivity characteristics (broad and narrow). The selectivity may be changed by interchanging plug-in filters, or, in some units, by throwing a switch. The broad IF selectivity for both transceivers is such that:

1. The 6-dB bandwidth is at least 30 kHz,
2. The 60-dB bandwidth is at most 63 kHz,
3. The 100-dB bandwidth is at most 80 kHz.

The narrow IF selectivity for the 546 characteristic transceiver is such that:

1. The 6-dB bandwidth is at least 13 kHz,
2. The 60-dB bandwidth is at most 37 kHz,
3. The 100-dB bandwidth is at most 47 kHz.

The narrow IF selectivity for the 566 characteristic transceiver is such that:

1. The 6-dB bandwidth is at least 16 kHz,
2. The 60-dB bandwidth is at most 30 kHz,
3. The 100-dB bandwidth is at most 37 kHz.

The 566A characteristic transceiver has only a narrow IF selectivity which is such that:

1. The 6-dB bandwidth is at least 16 kHz,
2. The 60-dB bandwidth is at most 34 kHz,
3. The 100-dB bandwidth is assumed at most 50 kHz.

The broad selectivity is used for 50-kHz channels. The narrow selectivity will be used for the 25-kHz channels.

The audio frequency response for all three receivers is such that:

1. From 300 Hz to 2,500 Hz, the response is essentially flat,

2. There is sharp cutoff below 300 Hz,

3. There is a sharp cutoff above 2,500 Hz with frequencies above 5,750 Hz attenuated at least 20 dB.

The characteristics of the ground receivers in the terrestrial system meet or exceed the characteristics of the airborne receivers.

All receivers in the terrestrial system are tuned to the center of the channel they are receiving even if the transmitter is offset from the center of the channel.

Terrestrial System Receiver Degradation Thresholds. This analysis will be concerned with the performance of the terrestrial system receivers in the presence of an interfering signal from an AEROSAT transmitter whose carrier frequency is 25 kHz away from the center of the channel being received. For all types of terrestrial system receivers, an undesired signal, 25 kHz away from the center of the channel being received and stronger than -63 dBW, (References 9, 10 and 11) may cause audible cross modulation. Since the narrow selectivity rejects signals below -63 dBW to below the noise level, the cross-modulation specification is the limiting factor for interference to terrestrial system receivers using the narrow selectivity.

Note that at -63 dBW, cross modulation is only "audible." It is not known at what undesired signal level, cross modulation becomes so severe that the desired communication is unintelligible.

An ECAC computer program, which models receiver performance in the presence of interference, was used to determine the degradation thresholds for the receivers using the broad selectivity. The computer program considers:

1. The type of receiver (AM, FM, PM, SSB, or FDM),
2. The IF bandwidth,
3. The IF selectivity characteristics,
4. Audio frequency response and rolloff characteristics,
5. The type of interference (AM, FM, PULSE, NONE, etc.),

6. The modulation on the interference (1000 Hz tone, 2000 Hz tone, voice shaped noise, no modulation, etc.),

7. The RF signal to noise ratio,

8. The RF signal to interference ratio,

9. The frequency separation between the signal and the interference.

Outputs of the program are:

1. The output signal-to-noise ratio at the speaker terminals,
2. The articulation index (AI).

Articulation index is a number between 0 and 1 that represents how well the desired communication can be understood. It differs from articulation score (AS) which is the average percent score that an average listener would get on a test where the listener hears a broadcast of random words (i.e. not sentences) and tries to identify the words. Note that for words in sentences, understanding would be higher.

AI is derived by purely mathematical means while AS is calculated from listener tests. An AS of 50% means that communication is such that only 50% of the words are understandable while an AI of 0.5 only means communication is better than for an AI of 0.4 and worse than for an AI of 0.6. However, for a particular type of interference, the relationship between AS and AI is approximately constant. The relationship between AS and AI for an FM voice signal interfering with AM is shown in FIGURE 21.[16]

DPSK interference on AM communications produces annoying sounds that cause listener fatigue, but the AS is much higher than for FM

[16] Kravitz, F., *Communications/Electronics Receiver Performance Degradation Handbook*, ESD-TR-73-014, ECAC, Annapolis, MD, July 1973.

voice interference on AM. Therefore AEROSAT voice communications would cause more interference to the terrestrial system than AEROSAT data communications would under the same conditions.

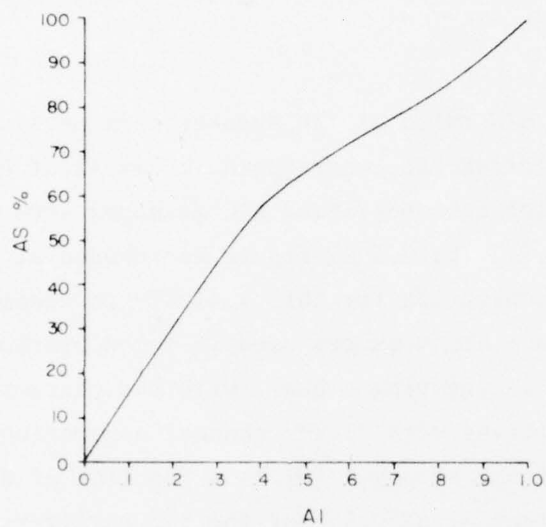


FIGURE 21. ARTICULATION SCORE AS A FUNCTION OF ARTICULATION INDEX, FOR FM VOICE OR AM VOICE.

Two types of receivers were modeled on the computer. An ARINC characteristic 546 and 566 transceiver using the broad selectivity was modeled, and since, in some areas of the world, some receivers don't meet the ARINC specifications, a "worst-case" receiver was also modeled.

The specifications for the worst-case receiver were the same as the ARINC characteristics except:

1. The sensitivity is -123 dBW (instead of -133.7 dBW),
2. The IF 6-dB bandwidth is 40 kHz,

3. The IF 60-dB bandwidth is 126 kHz,
4. The IF 100-dB bandwidth is 272 kHz.

The sensitivity characteristic is based on international regulations (Reference 5). The selectivity is that of three double-tuned IF stages with a bandwidth of 40 kHz. The ARINC characteristic broad selectivity is approximately that of five double-tuned IF stages with a bandwidth of 30 kHz.

A 4.74-dB S/N ratio at the speaker terminals, in the case where there is no interference, corresponds to an AI of 0.5. However, an experienced pilot can understand ATC messages 100% of the time at an AI of only 0.3.[17] The 0.5 AI figure was chosen as the threshold for acceptable communication for this analysis to accommodate inexperienced listeners and non ATC messages used in the operational control system. The case of an interfering signal, with the characteristics of AEROSAT voice communications with 25-kHz channel separation was modeled. Curves of undesired signal strength (U) as a function of desired signal strength, (D) for a constant AI of 0.5, for the two receivers are given in FIGURE 22. These curves will be referred to as the degradation threshold curves for the rest of this report. Due to cross modulation, the maximum undesired signal strength that can be tolerated is -63 dBW. The degradation threshold curves include this -63 dBW maximum but for that part of the curves the AI is not necessarily 0.5. The carrier offsets used in the terrestrial system do not affect the degradation thresholds.

CALCULATIONS

The Necessity of Interleaving

With terrestrial system channels centered at multiples of 50 kHz, it has been proposed that the AEROSAT channels be centered at odd

[17]Gierhart, G. D., Hubbard, R. W., and Glen, D. V., *Electrospace Planning and Engineering for the Air Traffic Environment*, FAA-RD-70-71, US Department of Commerce, Boulder, CO, December 1970.

multiples of 25 kHz. This technique, which locates the AREOSAT channels between the terrestrial system channels, is called interleaving.

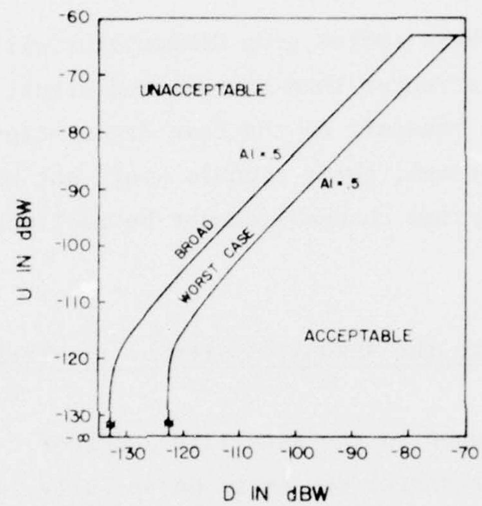


FIGURE 22. DEGRADATION THRESHOLD CURVES FOR THE CASE OF AEROSAT INTERFERENCE 25 kHz OFF TUNE TO TERRESTRIAL SYSTEM RECEIVERS.

The average signal strength of the satellite signal at the earth surface is given by:

Satellite EIRP	=	25 dBW
Propagation Loss	=	-166 dB
D_{avg}	=	-141 dBW

The average signal strength of a 25-watt signal (such as that radiated by an ARINC characteristic transmitter on an airplane) at a distance of 100 nautical miles, is given by:

Transmitter Output	=	14 dBW
Transmission Line Loss	=	-1 dB
Antenna Gain	=	0 dBi
Propagation Loss	=	-120 dB
U_{avg}	=	-107 dBW

The AEROSAT Phase Locked Loop Demodulator will not tolerate co-channel interference stronger than the desired signal. Therefore if the satellites were to transmit on the same frequencies as those used by the terrestrial system, their signals would not be received. Since the terrestrial system channels cannot be reallocated, interleaving is necessary.

Interference to the AEROSAT System by the Terrestrial System

Interference to the Satellite Receiver. FIGURE 4 shows the case where the terrestrial system is potentially interfering with the communication from the AEROSAT airborne transmitter to the satellite receiver. The ground stations and the airplanes as sources of interference are considered together because the distances are the same. This interference case is in the 131.4 to 132.0 MHz band.

The minimum desired-signal strength is given by:

Antenna Input Power	=	19 dBW
Minimum Airborne Antenna Gain	=	-2 dBi
Propagation Loss	=	-167 dB
System Margin	=	-11 dB
Satellite Antenna Gain	=	10 dBi
D_{min}	=	-151 dBW

System margin is the link margin defined in the MOU.

The maximum undesired signal strength (from transmitters in the US and Canada, to satellites over the Atlantic) is from a 500-watt transmitter at 131.8 MHz in Buffalo, New York. The maximum signal strength, U_{max} is given by:

EIRP	=	27 dBW
Propagation Loss	=	-167 dB
Multipath Maximum	=	5 dB
Scintillation Maximum	=	4 dB
Polarization Loss	=	-3 dB
Satellite Antenna Gain	=	10 dBi
U_{max}	=	-124 dBW

Therefore the minimum protection ratio, $(D/U)_{min}$, is given by:

$$(D/U)_{min} = -27 \text{ dB}.$$

A typical transmitter would have a power of 50 watts giving:

$$U_{max} = -134 \text{ dBW}$$

and

$$(D/U)_{min} = -17 \text{ dB}.$$

Since scintillation and multipath are rarely at a maximum simultaneously, the maximum undesired signal strength from a particular transmitter is rarely attained. The probability that the undesired signals from two transmitters would be at a maximum simultaneously is extremely low. Therefore, although there are many transmitters in each terrestrial

system channel, it is assumed that they do not combine to produce a higher undesired signal strength at a satellite than the highest undesired signal strength from any single transmitter.

The selectivity of the "satellite receiver" (see the discussion of the effective satellite receiver in the system description) must be sufficient to reject the maximum undesired signal strength from any transmitter in the 131.4 to 132.0 MHz band. By being offset 8 kHz from an exact multiple of 50 kHz, a ground transmitter carrier may be 17 kHz off tune from the center of an AEROSAT channel. However, all airborne transmitters and most US and Canadian ground transmitters with greater than 50-watt outputs are not offset. However, due to instability of up to ± 6 kHz, a transmitter that is not offset may be as little as 19 kHz off tune from the center of an AEROSAT channel. Outside the US and Canada, the incomplete data that has been supplied to ECAC indicates that offsets are not used in the 131.4 to 132.0 MHz band. This data also indicates that there are no undesired signals that exceed -124 dBW.

The selectivity requirements for the "satellite receiver" are different for different AEROSAT channels. APPENDIX A contains the US and Canadian data for use in calculating the selectivity requirements for specific AEROSAT channels. Assuming the satellite receiver will have the same selectivity characteristics for all channels, the selectivity requirements are:

1. Signals 19 kHz off tune at -124 dBW [$(D/U_{min}) = -27$ dB], and

2. Signals 17 kHz off tune at -128 dBW [$(D/U_{min}) = -23$ dB], must be rejected by the satellite receiver. In addition to the selectivity requirements, the satellite has a limited power budget. It may not be able to translate the undesired signals to the 5125 to 5250 MHz band and retransmit them without excessive power consumption.

Interference to the Airborne AEROSAT Receiver. FIGURES 5 and 6 show the cases where the terrestrial system is potentially interfering with the communication from the satellite to the AEROSAT airborne receiver. These interference cases are in the 125.4 to 126.0 MHz band.

The minimum desired signal strength for both cases is given by:

Satellite EIRP	=	+25 dBW
Propagation Loss	=	-166 dB
System Margin	=	-11 dB
Aircraft Antenna Gain	=	-2 dBi
D_{min}	=	-154 dBW.

For the case where a ground transmitter is the potential source of interference, the maximum undesired signal strength is given by:

$$U_{max} = 10 \log P + CF_{max} \tag{5}$$

where

P = the transmitter power, in watts

CF_{max} = the maximum coupling factor (as a function of distance) from FIGURE 18 (upper curve).

Therefore the protection ratio is given by:

$$(D/U)_{min} = -154 \text{ dBW} - 10 \log P - CF_{max}$$

where all terms have been defined previously.

The most powerful terrestrial system ground transmitter (in the US and Canada) in the 125.4 to 126.0 MHz band is 100 watts (20 dBW) and the CF_{max} from FIGURE 18 is -102 dB so the minimum D/U is -72 dB (for the US and Canada).

For the case where a terrestrial system airborne transmitter is the source of interference, the analysis is identical except P=50 watts maximum minus 1-dB line loss.

Therefore:

$$(D/U)_{min} = -154 \text{ dBW} - (16 \text{ dBW}) - CF_{max}$$
$$= -170 \text{ dB} - CF_{max}$$

where CF_{max} is the maximum coupling factor from FIGURE 19.

The minimum D/U that the AEROSAT VHF airborne receiver can tolerate is undefined. The minimum D/U that the AEROSAT VHF receiver will have to tolerate depends on how close to the 125.4 to 1260 MHz band terrestrial system the AEROSAT receiver will be operating. If an AEROSAT airplane were inside the area of coverage of a ground station operating in the band, then terrestrial system airplanes could get as close as 3 nmi to the AEROSAT airplane for an extended period of time. The CF_{max} between an AEROSAT airplane and a terrestrial system airplane at 3 nmi is -86 dB, resulting in a D/U of -84 dB. A D/U of -84 dB represents more interference than will be encountered due to any ground transmitter. Therefore -84 dB is the protection ratio required for AEROSAT to be able always to operate inside the area of coverage of a ground station. Since no offsets are used by airborne transmitters, the interfering signal will be at least 19 kHz off tune.

A receiver capable of rejecting an undesired signal only 19 kHz off tune and 84 dB above the desired signal level is very difficult

to build. Even if the selectivity is great enough to reject the signal, the front end may not be able to handle such a strong interfering signal. If the front end is designed so that the interfering signal does not overload, desensitize, produce intermodulation in, or otherwise disturb it, then the sensitivity may be compromised.

However, the D/U of -84 dB occurs rarely, and only when an AEROSAT airplane is inside the area of coverage of a terrestrial system ground station in the 125.4 to 126.0 MHz band. These coverage areas do not extend more than a few miles off shore (though they cover almost all land areas).

It is required that AEROSAT operate in all oceanic areas not covered by Extended Range VHF stations.

How much interference to the airborne AEROSAT receiver exists at the extreme limits of the Extended Range VHF coverage areas needs to be known. Since these stations are not in the 125.4 to 126.0 MHz band, the areas in which AEROSAT must operate do not overlap the areas where AEROSAT would experience severe interference. Maps showing the coverage areas of the Extended Range VHF stations in the US, Canada, and the North Atlantic Region are included in APPENDIX C. The maps in APPENDIX C show Extended Range coverage areas extending more than 200 nmi out over the ocean. The most powerful transmitter in the 125.4 to 126.0 MHz band (in the US and Canada) is 100 watts (20 dBW). The CF_{max} between a terrestrial system ground transmitter and an airborne AEROSAT receiver 200 nmi away is -123 dB, so the U_{max} is -103 dBW and the $(D/U)_{min}$ is -51 dB. The CF_{max} between a terrestrial system airborne transmitter and an airborne AEROSAT receiver 200 nmi away is -125 dB so the U_{max} from an airborne terrestrial system transmitter is -109 dBW and the $(D/U)_{min}$ is -45 dB. Since offsets up to 8 kHz are used in this band in Europe, the interfering signal may be only 17 kHz off tune.

For AEROSAT to be able always to operate in all oceanic areas not covered by Extended Range VHF stations, the AEROSAT VHF avionics receiver must be able to operate in the presence of undesired signals, 17 kHz off tune, 51 dB above the desired signal level. As mentioned earlier, for AEROSAT to be able always to operate over land, the AEROSAT VHF avionics receiver must be able to operate in the presence of interference 84 dB above the desired signal level.

These two requirements are the minimum and maximum requirements respectively. If the interference rejection capabilities of the AEROSAT VHF avionics receivers fall somewhere between the two requirements given above, then AEROSAT will always be able to operate less than 200 nmi away from the shore, but not always over land.

The receivers should be designed to reject as much interfering signal (17 to 19 kHz off tune) with a goal of being able to reject signals 19 kHz off tune, 84 dB above the desired signal level, without compromising sensitivity. To aid in achieving this design goal, the lock in range of the PLL should be within ± 17 kHz of the center of the channel.

Interference to the Terrestrial System by the AEROSAT System

The Satellite as a Source of Interference. FIGURES 6 and 7 show the cases where the satellite is potentially interfering with the terrestrial system. This interference is in the 125.4 to 126.0 MHz band. The maximum strength of the satellite signal to terrestrial system receivers (when the two transmitters are combined for maximum power) is given by:

Satellite EIRP	=	28 dBW
Propagation Loss	=	-166 dB
Multipath Maximum	=	6 dB
Scintillation Maximum	=	6 dB
Polarization Loss	=	-3 dB
Antenna Gain	=	0 dBi
U_{max}	=	-129 dBW.

The degradation threshold curves (FIGURE 22) show that for an undesired signal strength of -129 dBW, the desired signal strength that gives an AI of 0.5 is the same as for an undesired signal strength of -∞ dBW. Therefore, the satellite signal is not a significant source of interference.

The Airborne AEROSAT Transmitter as a Source of Interference. FIGURES 9 and 10 show the cases where the airborne AEROSAT transmitter is potentially interfering with the terrestrial system. This interference is in the 131.4 to 132.0 MHz band.

For the case where the airborne AEROSAT transmitter is potentially interfering with a particular terrestrial system ground receiver that is listening to nearby airplanes, the minimum desired signal strength is given by:

$$D_{min} = 13 \text{ dBW} + CF_{min} \tag{7}$$

where

13 dBW = the minimum EIRP for an airborne terrestrial system transmitter (25 W power out minus 1 dB line loss)

CF_{min} = the minimum coupling factor from FIGURE 17 (lower curve) for any airplane in the area of coverage of the ground station.

CF_{min} is found by finding the distance to the farthest point away from the ground station in the area of coverage, and using FIGURE 17 to obtain CF_{min}.

Given the minimum desired signal strength (D_{min}), the maximum allowable undesired signal strength (U_{max}) may be found by using:

1. The degradation threshold curves (FIGURE 22) for broad selectivity or worst-case selectivity receivers, or
2. U = -63 dBW for the narrow selectivity receivers.

Since the ground receivers meet the ARINC characteristics, the lower (worst case) curve in FIGURE 22 is not used. Also:

$$U_{max} = CF_{max} + 19 \text{ dBW} \tag{8}$$

where

19 dBW = the power delivered to the antenna (after line losses) by the airborne AEROSAT transmitter

CF_{max} comes from the upper curve of FIGURE 18.

For a given value of U, CF_{max} may be determined. Knowing CF_{max}, from FIGURE 18, a "minimum distance" can be obtained that is how far away from the ground station the AEROSAT airplane must be when it is transmitting. When the AEROSAT airplane is within the "minimum distance" of a particular ground station, its AEROSAT VHF transmitter must be off. The area where the VHF transmitter must be off will be referred to as the "interference area" for the rest of this report.

For narrow selectivity ground receivers, U_{max} = -63 dBW, therefore CF_{max} = -82 dB. However FIGURE 18 shows a CF_{max} of -102 dB or less. Therefore, there are no interference areas due to narrow selectivity ground receivers.

Broad selectivity ground receivers can experience interference from airborne AEROSAT VHF transmitters. Around each broad selectivity ground receiver will be an interference area described by a circle whose radius is equal to the "minimum distance." These circles may be drawn for the locations of all ground receivers, whose channels are adjacent to a particular AEROSAT channel. A plot of these circles on a map will depict the areas where operation of airborne AEROSAT VHF transmitters in that particular channel may cause interference. However, this map only shows the areas that are interference areas due to interference to ground receivers trying to listen to nearby airplanes. Interference to airborne receivers trying to listen to ground stations will generate (by a similar process) even larger interference areas (in most cases).

In an interference area, the AEROSAT VHF transceiver on an airplane *must not* be used. In the cases where the terrestrial system may interfere with the AEROSAT system (discussed earlier), the AEROSAT VHF subsystem may be used but will occasionally experience interference.

For the case where the airborne AEROSAT transmitter is interfering with an airborne receiver that is listening to a nearby ground station, the minimum desired signal is given by:

$$D_{min} = 10 \log P + CF_{min} \tag{9}$$

where

P = the power of the ground transmitter which the airborne receiver is listening to

CF_{min} = the minimum propagation factor (from FIGURE 18) between the airplane and the ground station. This is calculated for every possible airplane location in the area of coverage of every ground station.

Once again U is found from:

1. The degradation threshold curves for broad or worst case selectivity receivers, or

2. U = -63 dBW for narrow selectivity receivers.

As before:

$$CF_{max} = U_{max} - 19 \text{ dBW}, \tag{10}$$

but FIGURE 19 is used to determine the minimum distance.

For the narrow selectivity receivers, CF_{max} = -82 dB and the minimum distances is 1.8 nmi.

Although airplanes do occasionally approach each other to within 1.8 nmi, this distance is small enough that the AEROSAT interference to airborne terrestrial system receivers using the narrow selectivity is insignificant. There are 3 reasons for this conclusion.

1. At a separation distance of 1.8 nmi, cross modulation is only audible, not necessarily intolerable.

2. Airplanes flying in the same direction, and under ATC rules, are separated by at least 3 nmi. Airplanes flying in different directions would be in close proximity for only a few seconds.

3. Using all of the Collision Avoidance Systems,[18] in all possible instances, a separation distance of 1.8 nmi would be avoided.

For the broad or worst-case selectivity receivers, the minimum distance obtained from FIGURE 19 will usually be significant. Once again charts showing interference areas can be made. However, the production of the charts for this case differs from the production of the charts for the previous case.

For this case, each possible airplane location must be considered and a circle of "minimum distance" radius drawn around that location. For each ground station, there will be a collection of circles. This collection of circles describes an "interference area" associated with the ground station. The dozens of transmitters in the channels adjacent to a particular AEROSAT channel yield a total interference area.

Finally, the interference areas from both preceding cases are combined to form the final interference area for each particular AEROSAT channel. To prevent interference to the terrestrial system, AEROSAT VHF transmitters should be prohibited from emitting in the interference area designated for each specific AEROSAT channel.

The Sufficiency of Interleaving

As mentioned earlier, it is required that AEROSAT operate in all oceanic areas not covered by Extended Range VHF stations. It is necessary to know if the interference areas will make the above requirement impossible in some areas.

[18] *Airborne Collision Avoidance System, Statement of Airline Policy and Requirements and a Description of the System*, Air Navigation/Traffic Control Division, Air Transport Association of America ANTC Report No. NR. 117 Revision 10, 2 May 1971, corrected 27 September 1971.

In the gradual worldwide conversion to 25-kHz channel spacing, the US and Canada will be among the first to convert. Airplanes that may be flying in the US or Canada will be among the first airplanes to switch to the narrow selectivity. It is assumed that airplanes that fly as far out over the ocean as the outer regions of Extended Range VHF stations will also be among the first to switch to the narrow selectivity. Therefore it is not necessary for AEROSAT airplanes to avoid any of the Extended Range VHF coverage areas specifically.

The weakest terrestrial system ground transmitters encountered have an output of 5 watts. The coverage areas of such low power transmitters extend less than 50 nmi away from the ground stations. Therefore the CF_{min} (FIGURE 17) is -122 dB and the D is -115 dBW. From the degradation threshold curves (FIGURE 21), the maximum allowable U for the worst-case receivers is -109 dBW. Therefore, from Equation 10, the CF_{max} is -128 dBW, and from FIGURE 19 the minimum separation distance is approximately 230 nmi. Assuming that the coverage areas of the 5-watt terrestrial system transmitters are strictly over land, all areas more than 230 nmi offshore are not interference areas. APPENDIX C includes the coverage areas of the Extended Range VHF transmitters in the US, Canada, and the North Atlantic region. These coverage areas generally extend at least 250 nmi out over the ocean.

Therefore, even in the worst case, the coverage areas of the Extended Range stations extend beyond the interference areas. This means 25-channel separation is sufficient and that the proposed interleaved candidate frequency plan will yield a workable system.

Interference in the US and Canada

In this subsection, the general results developed in the calculations subsection will be applied to the specific interference cases

in the US and Canada. Each of the interference cases depicted in FIGURES 3 through 9 will be discussed. Planned satellite locations over the Pacific Ocean at 155° and 180° West longitude will be analyzed.

Interference to the AEROSAT Satellite

Receiver. This case, which is in the 131.4 to 132.0 MHz band, is shown in FIGURE 4.

As discussed in the calculations subsection, the maximum undesired signal strength at the satellites over the Atlantic Ocean from transmitters in the US and Canada is -124 dBW. For use in specific calculations, a list of all ground transmitters in the US and Canada, in the 131.4 to 132.0 MHz band, which use omnidirectional antennas, is contained in APPENDIX A. This list includes maximum received power at satellites at 15°, 40°, 155°, and 180° West longitude.

There are 3 ground transmitters in the US and Canada in the 131.4 to 132.0 MHz band that use directional antennas.

1. Mount Haleakala, Hawaii, 20°42'42" North latitude, 156°15'33" West longitude. A 1,000-watt transmitter is coupled to a 17.2-dBi gain antenna with 0.5-dB line loss. The antenna beam has an elevation angle of 0°, an azimuth of 054°T, and a horizontal 3-dB beamwidth of 32°. The carrier frequency is 131.95 MHz. The azimuth to the satellite at 180° West longitude would be 231.2°T and the azimuth to the satellite at 155° West longitude would be 176.4°T, so the satellites would not be in the mainbeam of the antenna. The maximum sidelobe gain is assumed to be 0 dBi. Therefore, the maximum received signal strength at the Pacific satellites would be:

Transmitter Power	=	30 dBW
Line Loss	=	-.5 dB
Antenna Gain	=	0 dB
Propagation Factor	=	-166.1 dB
Multipath Maximum	=	5.7 dB
Scintillation Maximum	=	0 dB
Polarization Loss	=	-3 dB
Satellite Antenna Gain	=	10 dB
		-124 dBW.

The Atlantic satellites would be over the horizon and therefore their received signal strengths can be neglected.

2. San Francisco, California, 37°30'23" North latitude, 122°22'16" West longitude. A 1,000-watt transmitter is coupled to a 21-dB gain antenna with a 2-dB line loss. The antenna beam has an elevation angle of 0° an azimuth of 252°T, a 3-dB horizontal beamwidth of 20°, and a vertical 3-dB beamwidth of 5° to 10°. The carrier frequency is 131.95 MHz. The azimuth to the satellite at 180° West longitude would be 248.9°T and the elevation angle would be 16.8°. The azimuth to the satellite at 155° West longitude would be 226.4°T and the elevation angle would be 34.8°. Due to the narrow vertical beamwidth, both satellites would not be in the mainbeam of the antenna and the maximum received signal strength at the Pacific satellites would be approximately the same as from Mount Haleakala. The Atlantic satellites would be over the horizon and their received signal strengths can be neglected.

3. Santa Ynez, California, 34°31'33" North latitude, 119°58'43" West longitude. A 1,000-watt transmitter is coupled to a 16-dBi gain antenna with 0.4-dB line loss. The antenna beam has an elevation angle of 0°, an azimuth of 245°T and a horizontal 3-dB beamwidth of 32°. The vertical beamwidth is the same as the horizontal except that since vertical polarization is used, an extra factor of:

$$\frac{\cos^2 (\pi/2 \sin E)}{\cos^2 E} \tag{11}$$

where

E = the elevation angle.

This factor is introduced due to the radiation pattern of the vertically polarized elements. The carrier frequency is 131.944 MHz. The azimuth to the satellite at 155° West longitude would be 231.0°T and the elevation angle would be 35.4°. Therefore the satellite would not be in the mainbeam of the antenna and the maximum received signal strength at the satellite would be approximately the same as from Mount Haleakala. The Atlantic satellites would be over the horizon and their received signal strengths can be neglected. The azimuth to the satellite at 180° West longitude would be 251.9°T and the elevation angle would be 16.0°. Consequently:

$$\frac{\cos^2 [\pi/2 \sin (16°)]}{\cos^2 (16°)} = .8917 = -0.5 \text{ dB}.$$

Therefore the antenna gain in the direction of the satellite would be 12.5 dB. The maximum received signal strength at the satellite at 180° West longitude would be:

Transmitter Power	=	30.0 dBW
Line Loss	=	-0.4 dB
Antenna Gain	=	12.5 dB
Propagation Factor	=	-166.9 dB
Multipath Maximum	=	5.2 dB
Scintillation Maximum	=	0.0 dB
Polarization Loss	=	-3.0 dB
Satellite Antenna Gain	=	10.0 dB
		-112.6 dBW.

This signal is 19 kHz off tune from the 131.925-MHz AEROSAT channel and is 31 kHz off tune from the 131.975-MHz AEROSAT channel. If an AEROSAT satellite cannot handle this interference without modification, then the satellite at 180° West longitude must be modified. There are three possible solutions.

1. Modify the satellite so that it will be able to handle the -112.6-dBW undesired signal (a band reject filter tuned to 131.944 MHz is a possible method).
2. Move the satellite at 180° West longitude out of the undesired signal beam. However to reduce the maximum undesired signal level to -124 dBW, the satellite must be located east of 170° West longitude or west of 155° East longitude. At 170° West longitude the satellite would be too close to the satellite at 155° West longitude and simultaneous eclipse (where both satellites are in the earth's shadow) would be possible.
3. Do not use the satellite at 180° West longitude for the channels at 131.925 and 131.975 MHz, (that is operate it in the 131.4 to 131.9 MHz band) and design the satellite so that it rejects signals above 131.9 MHz.

Interference to the AEROSAT Airborne Receiver. These cases, which are in the 125.4 to 126.0 MHz band, are shown in FIGURES 5 and 6.

In the interference to the AEROSAT system by the terrestrial system subsection, it was shown that depending on how much of the 17 to 19 kHz off-tune interference the AEROSAT VHF avionics receiver can tolerate, the AEROSAT VHF subsystem will be able to operate closer than 200 nmi away from the shore, or, over land. Since offsets are not used in the US and Canada in this band, and since 25-kHz channels will be implemented in the US and Canada by the time the AEROSAT system is operational, all interfering signals will be at least 21-kHz off tune

(due to ± 4 kHz stability). Therefore, there will be less interference to the AEROSAT system near the US and Canada than near countries that use offsets and/or 50-kHz spacing. For general information purposes, a list of all ground transmitters in the US and Canada is included in APPENDIX B.

The Satellite as a Source of Interference. These cases, which are in the 125.4 to 126.0 MHz band, are shown in FIGURES 7 and 8. As shown in the calculations subsection, the satellites are not significant sources of interference.

The Airborne AEROSAT Transmitter as a Source of Interference. These cases, which are in the 131.4 to 132.0 MHz band, are shown in FIGURES 9 and 10. Since 25-kHz channels will be implemented in the US and Canada by the time the AEROSAT system is operational there will be no interference areas (where the AEROSAT VHF airborne transceiver *must not* be used).

SECTION 4

RESULTS

RESULTS

1. For the AEROSAT VHF subsystem to meet the minimum requirement that it be able to operate in all oceanic areas not covered by Extended Range VHF stations without interfering with or experiencing interference from systems presently operating in the same band, the following conditions must be satisfied.

a. The AEROSAT avionics receivers must be able to operate in the presence of undesired signals 17 kHz off tune and 51 dB above the minimum desired signal level.

b. For the Atlantic system, the "effective satellite receiver" must be able to operate in the presence of undesired signals 27 dB above the minimum desired signal level and 19 kHz off tune, and in the presence of undesired signals 23 dB above the minimum desired-signal level and 17 kHz off tune. Both selectivity and the satellite power budget should be considered in meeting this requirement.

c. For the Pacific system, the "effective satellite receiver" must meet all the Atlantic system requirements, and the "effective satellite receiver" at 180° West longitude must be able to operate in the presence of an undesired signal 38.4 dB above the minimum desired signal level, at 131.944 MHz.

2. For the AEROSAT VHF subsystem to exceed the minimum requirement discussed in Result 1, that is, to operate in the coverage area of an Extended Range VHF station, or overland, the following conditions must be satisfied.

a. In areas where the terrestrial system receivers are not using the narrow selectivity, there will be "interference areas"

as described in the ANALYSIS section (under Interference to the Terrestrial System by the AEROSAT system). When an AEROSAT airplane is in an interference area, its AEROSAT VHF transceiver must not be used.

b. In areas where the terrestrial system receivers are using the narrow selectivity, AEROSAT VHF communications may be used without any restrictions. However, depending on the ability of the AEROSAT VHF avionics receiver to operate in the presence of adjacent channel interference, the AEROSAT VHF satellite-to-aircraft communications may occasionally experience interference.

c. For AEROSAT VHF communications never to experience interference for all possible locations of the AEROSAT airplane, the AEROSAT VHF avionics receiver must be able to operate in the presence of undesired signals, 19-kHz off tune, 84 dB above the minimum desired signal level.

3. In the US and Canada, the terrestrial system receivers will be using the narrow selectivity. Therefore, AEROSAT VHF communications may be used without any restrictions. However, unless the AEROSAT VHF avionics receiver is able to operate in the presence of undesired signals, 19-kHz off tune, 84 dB above the minimum desired signal level, AEROSAT VHF satellite-to-aircraft communications will suffer occasional interference.

APPENDIX A

TRANSMITTERS IN THE US AND CANADA IN THE 131.4 to 132.0 MHz BAND

TABLE A-1 is a list of all the ground based transmitters in the US and Canada in the 131.4 to 132.0 MHz band which use omni-directional antennas. Received powers at satellite locations above 15°, 40°, 155°, and 180° West longitude are included in the list.

The column headings in TABLE A-1 are described below:

FREQ IN MHz - gives the exact carrier frequency of each transmitter including offset. The transmitters are listed by frequency.

CALL LETTERS - the first four characters of the call sign of each transmitter.

CITY - ground-station location.

STATE OR PROVINCE - ground-station location.

LATITUDE - ground-station location.

LONGITUDE - ground-station location.

TRANSMITTER POWER IN WATTS - ground-station transmitter power.

SATELLITE AT 15 DEG. W. - for the geostationary satellite at 15° West longitude, calculated values are given for the elevation angle from the ground station to the satellite (ELEV. ANGLE), received signal strength (RECEIVED POWER IN dBW) from both the ground station (GROUND) and an aircraft in the vicinity of the ground station (ACFT). The received signal strength is the maximum received signal strength at the satellite antenna terminals including:

a. The transmitter power - For the airborne transmitters, the maximum power of 50-watts is used.

b. The transmitting antenna gain and line losses.

c. The free-space propagation factor.

d. Multipath - for maximum signal strength, the factor is 20 log (1 + RD) where R is the reflection coefficient for sea water and D is the divergence factor.

e. Scintillation - the values which are exceeded 1% of the time in TABLE 1 are used.

f. Satellite antenna gain.

The scintillation and multipaths are such that the "received power in dBW" is exceeded approximately 0.1% of the time. For elevation angles less than 10°, the elevation angles are not accurate due to atmospheric refraction and the received signal strengths are unpredictable and are therefore not shown.

SATELLITE AT 40 DEG. W. - similar to the satellite at 15° W., and similar values for the satellite at 40° West longitude.
SATELLITE AT 155 DEG. W. - similar values for the satellite at 155° West longitude.
SATELLITE AT 180 DEG. W. - similar values for the satellite at 180° West longitude.

TABLE A-1

TRANSMITTERS IN THE US AND CANADA IN THE 131.4 TO 132.0 MHz BAND
(Page 1 of 9)

							SATELLITE AT 15 DEG W			SATELLITE AT 40 DEG W			SATELLITE AT 155 DEG W			SATELLITE AT 180 DEG W		
FREQ IN MHZ	CALL LETTERS	CITY	STATE OR PROVINCE	LATITUDE	LONGITUDE	TRANSMITTER POWER IN WATTS	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT
131.3920	KPV5	YOUNGSTOWN	OH	411320N	803330W	50.0	9.60			27.15	-135.	-136.	2.95			-15.47		
131.3940	KRN5	FLINT	MI	435800N	834600W	50.0	6.50			23.36	-134.	-135.	4.73			-12.95		
131.3960	KUK4	SOUTH BEND	IN	414115N	862010W	50.0	5.20			23.07	-135.	-136.	7.14			-11.26		
131.4000	WHW3	ANCHORAGE	AK	611000N	1495900W	10.0	-27.62			-1[illegible].75			20.60	-138.	-132.	16.36	-139.	-133.
131.4000	WBU2	ARLINGTON	VA	385100N	77 200W	10.0	12.98	-144.	-136.	31.02	-143.	-137.	.65			-18.32		
131.4000	WBT9	ATLANTA	GA	333920N	842549W	10.0	8.45			28.90	-144.	-138.	7.45			-13.11		
131.4000	WFJ9	BOSTON	MA	422200N	71 000W	10.0	16.08	-142.	-136.	31.95	-141.	-135.	-4.24			-21.98		
131.4000	WFH4	CHICAGO	IL	413010N	873245W	51.0	4.35			22.36	-135.	-136.	8.07			-10.40		
131.4000	WMH4	DALLAS	TX	325100N	965100W	10.0	-1.82			19.16	-145.	-139.	18.05	-145.	-139.	-2.93		
131.4000	WCO6	FT MYERS	FL	263500N	815200W	6.5	12.10	-147.	-139.	34.63	-146.	-138.	6.40			-15.64		
131.4000	WLX2	GAINESVILLE	FL	294100N	821600W	6.5	11.12	-147.	-139.	32.73	-146.	-138.	6.30			-15.11		
131.4000	WHN9	NEW YORK	NY	403628N	734933W	50.0	14.77	-136.	-137.	31.75	-135.	-136.	-2.00			-20.36		
131.4000	KFI2	NIAGRA FALLS	NY	43 615N	785700W	50.0	10.17	-135.	-136.	26.87	-134.	-135.	1.45			-16.38		
131.4000	KIN6	OCALA	FL	291038N	821335W	50.0	11.27	-138.	-139.	33.04	-137.	-138.	6.34			-15.18		
131.4000	KVO7	PAGO PAGO	AS	141948S	1704248W	10.0	-65.58			-45.26			65.29	-143.	-137.	70.01	-143.	-137.
131.4000	KVS9	PHILADELPHIA	PA	395700N	75 905W	10.0	14.02	-144.	-138.	31.43	-143.	-137.	-.93			-19.52		
131.4000	KWA7	SAN FRANCISCO	CA	373023N	1222216W	50.0	-21.74			-2.61			34.79	-137.	-138.	16.81	-138.	-139.
131.4000	WWN3	SAN JUAN	PR	182630N	66 022W	10.0	29.09	-144.	-138.	53.34	-144.	-138.	-7.67			-30.21		
131.4000	KHT7	SARASOTA	FL	272300N	823300W	10.0	11.33	-145.	-139.	33.65	-144.	-138.	6.90			-15.01		
131.4000	WGM5	ST CROIX	VI	174200N	644800W	10.0	30.49	-144.	-138.	54.89	-144.	-138.	-8.78			-31.35		
131.4000	KFP2	ST THOMAS	VI	182000N	645830W	10.0	30.15	-144.	-138.	54.34	-144.	-138.	-8.63			-31.12		
131.4000	WHT8	WAKE ISLAND	WK	191700N	1663900E	10.0	-73.17			-61.67			41.21	-144.	-138.	62.71	-143.	-137.
131.4040	KUK3	VANDALIA	OH	395433N	841230W	50.0	7.21			25.55	-136.	-137.	5.97			-12.92		
131.4500	WIC2	ALEXANDRIA	LA	312400N	921800W	5.0	2.16			23.52	-147.	-138.	14.64	-148.	-139.	-6.67		
131.4500	WFB5	ATLANTA	GA	333922N	842600W	10.0	8.43			28.89	-144.	-138.	7.46			-13.10		
131.4500	WRH2	BOSTON	MA	422200N	71 000W	50.0	16.08	-135.	-136.	31.95	-134.	-135.	-4.24			-21.98		
131.4500	KR69	DETROIT	MI	421344N	832329W	50.0	7.24			24.70	-134.	-135.	4.85			-13.35		
131.4500	KAD8	HONOLULU	HI	212000N	1575700W	10.0	-53.19			-33.13			64.80	-143.	-137.	58.67	-144.	-138.
131.4500	WDJ6	JACKSONVILLE	FL	302930N	814100W	10.0	11.45	-145.	-139.	32.78	-144.	-138.	5.67			-15.54		
131.4500	KWH9	KANSAS CITY	MO	391742N	944330W	5.0	-.72			18.33	-146.	-137.	14.14	-148.	-139.	-5.01		
131.4500	KAC5	KNOXVILLE	TN	354900N	84 000W	10.0	8.32			28.04	-144.	-138.	6.67			-13.32		
131.4500	KYA9	LAS VEGAS	NV	36 500N	115 900W	10.0	-16.49			3.30			30.90	-144.	-138.	11.57	-145.	-139.
131.4500	KQX2	LOS ANGELES	CA	335628N	1182404W	10.0	-19.26			.94			34.62	-144.	-138.	14.84	-145.	-139.
131.4500	KTI6	MILWAUKEE	WI	425654N	875407W	50.0	3.78			21.33	-134.	-135.	7.95			-10.10		
131.4500	KAN5	MINNEAPOLIS	MN	445100N	931400W	50.0	-.35			16.81	-134.	-135.	11.07	-138.	-139.	-6.35		
131.4500	KKL7	NEW ORLEANS	LA	295900N	901500W	10.0	4.10			25.84	-144.	-138.	13.22	-145.	-139.	-8.39		
131.4500	KFH5	NEW YORK	NY	403710N	734035W	50.0	14.88	-136.	-137.	31.82	-135.	-136.	-2.12			-20.47		
131.4500	KUP8	NEWARK	NJ	404134N	741023W	50.0	14.48	-136.	-137.	31.48	-135.	-136.	-1.75			-20.10		
131.4500	KHI7	PHILLIPSBURG	PA	405315N	78 515W	50.0	11.52	-136.	-137.	28.94	-135.	-136.	1.16			-17.28		
131.4500	KYQ5	SAN DIEGO	CA	324400N	1171100W	10.0	-18.44			2.09			34.49	-144.	-138.	14.17	-145.	-139.
131.4960	KUJ9	VIENNA	OH	411330N	804000W	50.0	9.51			27.08	-135.	-136.	3.04			-15.39		
131.4920	KHZ2	ETTERS	PA	401000N	765000W	50.0	12.69	-136.	-137.	30.23	-135.	-136.	.32			-18.28		
131.5000	KFV7	BUFFALO	NY	423500N	783432W	50.0	10.62	-135.	-136.	27.46	-134.	-135.	1.26			-16.72		
131.5000	WIA4	CHICAGO	IL	415900N	875400W	5.0	3.98			21.85	-145.	-136.	8.21			-10.12		
131.5000	KEL4	EAU CLAIRE	WI	445200N	912900W	6.5	.87			17.95	-142.	-134.	9.86			-7.57		
131.5000	KUI3	JENNERSTOWN	PA	401245N	79 710W	50.0	10.97	-136.	-137.	28.75	-135.	-136.	2.05			-16.62		
131.5000	WEJ2	MARSHFIELD	WI	443800N	901100W	5.0	1.82			18.91	-143.	-134.	9.04			-8.47		
131.5000	KIL8	MIAMI	FL	254827N	801705W	200.0	13.70	-132.	-139.	36.41	-131.	-138.	5.07			-17.05		
131.5000	WPL3	MINNEAPOLIS	MN	445300N	931300W	6.5	-.35			16.81	-142.	-135.	11.05	-147.	-139.	-6.36		
131.5000	KUQ7	NEW YORK	NY	403628N	734930W	200.0	14.77	-130.	-137.	31.75	-129.	-136.	-2.00			-20.36		
131.5000	WFV4	PEORIA	IL	404000N	894100W	10.0	2.90			21.32	-143.	-137.	9.91			-8.83		
131.5000	KXM5	ROCKFORD	IL	421220N	89 530W	5.0	3.07			20.93	-144.	-135.	9.01			-9.26		
131.5000	KMK8	SAN FRANCISCO	CA	373700N	1222200W	10.0	-21.72			-2.62			34.71	-144.	-138.	16.77	-145.	-139.
131.5000	KFI9	SHEBOTGAN FALLS	WI	434600N	875100W	10.0	3.65			20.89	-141.	-135.	7.67			-10.11		
131.5000	WEI8	STEVENS POINT	WI	443300N	893200W	5.0	2.30			19.38	-143.	-134.	8.62			-8.92		
131.5000	KHU9	STURGEON BAY	WI	445000N	872500W	6.5	3.72			20.56	-142.	-134.	7.07			-10.38		
131.5000	KFI6	TOMBALL	TX	30 500N	953400W	10.0	-.51			21.22	-144.	-138.	17.83	-145.	-139.	-3.86		
131.5000	WDP6	WISCONSIN RAPIDS	WI	442200N	895000W	5.0	2.12			19.28	-143.	-134.	8.89			-8.71		
131.5040	WMZ8	LEICESTER	MA	421600N	715400W	50.0	15.49	-135.	-136.	31.54	-134.	-135.	-3.57			-21.38		
131.5080	KFC2	BINGHAMTON	NY	421200N	755900W	50.0	12.60	-135.	-136.	29.28	-134.	-135.	-.58			-18.57		

TABLE A-1

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FREQ IN MHZ	CALL LETTERS	CITY	STATE OR PROVINCE	LATITUDE	LONGITUDE	TRANSMITTER POWER IN WATTS	SATELLITE AT 15 DEG W ELEV ANGLE IN DEG	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 40 DEG W ELEV ANGLE IN DEG	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 155 DEG W ELEV ANGLE IN DEG	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 180 DEG W ELEV ANGLE IN DEG	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW ACFT
131.5440	WNU9	BANGOR	ME	444800N	684900W	50.0	16.46	-134.	-135.	31.02	-133.	-134.	-5.94			-22.86		
131.5440	WMR9	MOLINE	IL	412530N	902600W	10.0	2.21			20.41	-142.	-136.	10.24	-145.	-139.	-8.28		
131.5500	KKB5	DALLAS-FT.WORTH	TX	325422N	97 240W	50.0	-1.98			18.99	-138.	-139.	18.19	-138.	-139.	-2.78		
131.5500	KQV6	HOLLAND	OH	413602N	834528W	51.0	7.13			24.84	-135.	-136.	5.25			-13.13		
131.5500	WNU9	NEW YORK	NY	403900N	734723W	10.0	14.78	-143.	-137.	31.73	-142.	-136.	-2.03			-20.38		
131.5500	KEE6	ORLANDO	FL	283000N	812500W	6.0	12.11	-147.	-139.	34.05	-146.	-138.	5.73			-15.90		
131.5500	WOR7	PASCO	WA	461600N	119 700W	5.0	-17.95			-1.17			26.28	-147.	-138.	11.13	-148.	-139.
131.5500	KXH4	PULLMAN	WA	464500N	117 700W	10.0	-16.57			.12			24.86	-144.	-138.	9.63		
131.5500	KCW7	SEATTLE	WA	472700N	1221800W	10.0	-19.76			-3.45			26.95	-144.	-138.	12.71	-145.	-139.
131.5500	WOL7	SPOKANE	WA	473800N	1173200W	10.0	-16.71			-.30			24.43	-144.	-138.	9.58		
131.5500	KYA8	WALLA WALLA	WA	46 600N	1181700W	10.0	-17.43			-.57			25.97	-144.	-138.	10.64	-145.	-139.
131.5500	WOQ4	YAKIMA	WA	463400N	1203200W	10.0	-18.81			-2.17			26.78	-144.	-138.	11.94	-145.	-139.
131.5560	KSG7	CHICAGO	IL	42 250N	875900W	51.0	3.91			21.77	-134.	-135.	8.26			-10.06		
131.5920	KZT7	BOSTON	MA	422200N	71 000W	50.0	16.08	-135.	-136.	31.95	-134.	-135.	-4.24			-21.08		
131.5920	KIE4	HUNTSVILLE	AL	344415N	863150W	50.0	6.49			26.70	-137.	-138.	8.96			-11.39		
131.5920	KDS6	KNOXVILLE	TN	354845N	835825W	50.0	8.35			28.07	-137.	-138.	6.65			-13.35		
131.5920	WWL5	TEXARKANA	TX	33 141N	94 054W	50.0	.54			21.47	-137.	-138.	15.62	-138.	-139.	-5.30		
131.5960	WDV3	MEMPHIS	TN	35 230N	895800W	50.0	3.61			23.86	-137.	-138.	11.71	-138.	-139.	-8.62		
131.5960	KEA5	NEW YORK	NY	403630N	734935W	50.0	14.77	-136.	-137.	31.75	-135.	-136.	-2.00			-20.36		
131.6000	W667	ATLANTA	GA	333720N	843422W	50.0	8.33			28.80	-137.	-138.	7.58			-12.99		
131.6000	KSG7	CHICAGO	IL	42 250N	875900W	51.0	3.91			21.77	-134.	-135.	8.26			-10.06		
131.6000	KMS7	DALLAS-FT.WORTH	TX	325400N	97 200W	50.0	-1.98			18.99	-138.	-139.	18.19	-138.	-139.	-2.78		
131.6000	WFN9	LOS ANGELES	CA	335600N	1182400W	50.0	-19.26			.94			34.62	-137.	-138.	14.84	-138.	-139.
131.6000	KDX4	MIAMI	FL	254700N	801700W	10.0	13.70	-145.	-139.	36.42	-144.	-138.	5.07			-17.05		
131.6000	KCA7	PROVIDENCE	RI	414345N	712545W	10.0	16.06	-142.	-136.	32.25	-142.	-136.	-3.89			-21.83		
131.6000	KEG4	ROCHESTER	NY	43 738N	773957W	10.0	11.09	-142.	-136.	27.63	-141.	-135.	.51			-17.28		
131.6000	KEB9	SYRACUSE	NY	425648N	76 704W	50.0	12.24	-135.	-136.	28.66	-134.	-135.	-.58			-18.37		
131.6000	WOB6	WINSLOW	AZ	35 150N	1104320W	50.0	-13.12			7.09			28.24	-137.	-139.	8.24		
131.6040	KFV7	BUFFALO	NY	424000N	783700W	50.0	10.55	-135.	-136.	27.38	-134.	-135.	1.28			-16.67		
131.6040	WEY3	FT WORTH	TX	325010N	97 500W	50.0	-2.01			18.98	-138.	-139.	18.25	-138.	-139.	-2.74		
131.6040	KDD6	HARTFORD	CT	415600N	724028W	50.0	15.08	-135.	-136.	31.38	-135.	-136.	-2.98			-20.92		
131.6040	WFC6	NASHVILLE	TN	36 800N	864100W	50.0	6.09			25.85	-137.	-138.	8.77			-11.21		
131.6080	WDE3	ALBANY	NY	423720N	74 035W	200.0	13.86	-129.	-136.	30.10	-128.	-135.	-2.08			-19.88		
131.6080	KKO4	LITTLE ROCK	AR	344400N	921400W	50.0	1.80			22.20	-137.	-138.	13.64	-138.	-139.	-6.80		
131.6420	KDQ3	TULSA	OK	36 850N	955300W	50.0	-1.31			18.73	-138.	-139.	16.14	-138.	-139.	-3.93		
131.6460	WEZ3	ST LOUIS	MO	383900N	902100W	50.0	2.74			21.85	-137.	-138.	11.00	-138.	-139.	-8.33		
131.6500	WEW8	ARLINGTON	VA	385100N	77 200W	10.0	12.98	-144.	-138.	31.02	-143.	-137.	.65			-18.32		
131.6500	WKO9	BURLINGTON	VT	442800N	73 900W	10.0	13.71	-141.	-135.	29.13	-140.	-134.	-2.87			-20.10		
131.6500	WEY4	CHICAGO	IL	415710N	875305W	51.0	4.00			21.88	-135.	-136.	8.21			-10.13		
131.6500	KEE7	CORNWALL HEIGHTS	PA	40 000N	75 100W	8.0	14.11	-144.	-137.	31.47	-143.	-136.	-1.03			-19.61		
131.6500	WEY7	GRAND PRAIRIE	TX	324645N	97 326W	50.0	-1.98			19.03	-138.	-139.	18.25	-138.	-139.	-2.76		
131.6500	WSH2	GROTON	CT	411900N	72 300W	10.0	15.77	-142.	-136.	32.21	-142.	-136.	-3.39			-21.47		
131.6500	KKH3	HONOLULU	HI	212000N	1575700W	5.0	-53.19			-33.13			64.80	-146.	-137.	54.67	-147.	-138.
131.6500	KXR9	ISLIP	NY	404800N	73 600W	6.5	15.22	-145.	-137.	32.02	-144.	-136.	-2.56			-20.83		
131.6500	KUM7	LOS ANGELES	CA	335600N	1182400W	10.0	-19.26			.94			34.62	-144.	-138.	14.84	-145.	-139.
131.6500	KRJ5	MIAMI	FL	254700N	801700W	6.5	13.70	-147.	-139.	36.42	-146.	-138.	5.07			-17.05		
131.6500	WCE7	NEWARK	NJ	404134N	741023W	10.0	14.48	-143.	-137.	31.48	-142.	-136.	-1.75			-20.10		
131.6500	WIX3	PHILADELPHIA	PA	40 500N	75 100W	50.0	14.08	-136.	-137.	31.41	-135.	-136.	-1.04			-19.60		
131.6500	KET3	PLATTSBURG	NY	444100N	733100W	6.5	13.37	-143.	-135.	28.76	-142.	-134.	-2.64			-19.81		
131.6500	KBH6	SARANAC LAKE	NY	442300N	741200W	6.5	13.02	-143.	-135.	28.63	-142.	-134.	-2.12			-19.42		
131.6500	CYT	TORONTO	ON	434050N	793930W	50.0	9.49			26.07	-134.	-135.	1.86			-15.83		
131.6500	KFD4	TRENTON	NJ	401630N	744930W	50.0	14.16	-136.	-137.	31.40	-135.	-136.	-1.21			-19.71		
131.6500	KEV7	WATERTOWN	NY	435900N	76 100W	6.5	11.93	-143.	-136.	27.94	-142.	-135.	-.79			-18.27		
131.6540	WAY2	SPRINGFIELD	MO	371400N	932300W	50.0	.56			20.22	-138.	-139.	13.80	-138.	-139.	-5.95		
131.6580	KDQ2	OKLAHOMA CITY	OK	352300N	973600W	50.0	-2.63			17.65	-138.	-139.	17.78	-138.	-139.	-2.50		
131.6580	KSH8	SPRINGFIELD	IL	395030N	894015W	51.0	3.06			21.76	-136.	-137.	10.14	-138.	-139.	-8.85		

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FREQ IN MHZ	CALL LETTERS	CITY	STATE OR PROVINCE	LATITUDE	LONGITUDE	TRANSMITTER POWER IN WATTS	SATELLITE AT 15 DEG W			SATELLITE AT 40 DEG W			SATELLITE AT 155 DEG W			SATELLITE AT 180 DEG W		
							ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT
131.6940	KAN4	BISMARCK	ND	464700N	1004500W	50.0	-5.71			11.04	-133.	-134.	15.20	-138.	-139.	-1.35		
131.6940	KAG8	FARGO	ND	465504N	964858W	50.0	-3.06			13.54	-133.	-134.	12.62	-138.	-139.	-4.03		
131.6940	WGB7	PHILADELPHIA	PA	395300N	751400W	50.0	13.99	-137.	-138.	31.42	-136.	-137.	-.86			-19.47		
131.7000	KJV4	ARLINGTON	VA	385042N	77 236W	50.0	12.98	-137.	-138.	31.03	-136.	-137.	.65			-18.32		
131.7000	WAW2	BAKERSFIELD	CA	352554N	119 300W	10.0	-19.57			.24			34.09	-144.	-138.	14.91	-145.	-139.
131.7000	KOD7	BILLINGS	MT	454800N	1083200W	50.0	-10.97			6.16			20.57	-138.	-139.	4.13		
131.7000	KVK4	CHANTILLY	VA	385700N	772700W	50.0	12.63	-137.	-138.	30.68	-136.	-137.	.96			-18.00		
131.7000	WDX2	EVANSTON	WY	411600N	1105800W	50.0	-12.93			5.56			24.83	-137.	-138.	6.97		
131.7000	WPJ7	GRANDFORKS	ND	455706N	971108W	10.0	-3.23			13.72	-140.	-134.	13.28	-145.	-139.	-3.69		
131.7000	KAH5	JAMESTOWN	ND	465500N	984100W	4.4	-4.33			12.33	-143.	-134.	13.83	-149.	-139.	-2.76		
131.7000	VFR2	REGINA	SA	502325N	1043630W	50.0	-8.32			7.27			15.62	-138.	-139.	.56		
131.7000	VFJ7	SAULT ST. MARIE	ON	462900N	843000W	50.0	5.32			21.34	-132.	-133.	4.63			-12.28		
131.7000	WJR2	SEATTLE	WA	472700N	1221800W	5.0	-19.76			-3.45			26.95	-147.	-138.	12.71	-148.	-139.
131.7000	VBA	THUNDER BAY	ON	482630N	892150W	50.0	1.65			17.34	-132.	-133.	7.26			-9.02		
131.7000	VFW5	WINNIPEG	MA	495400N	971400W	50.0	-3.66			11.92	-132.	-133.	11.58	-138.	-139.	-4.02		
131.7060	WOC7	BAKER	MT	462200N	1041630W	50.0	-8.07			8.87			17.62	-138.	-139.	1.10		
131.7060	KRK4	CLEVELAND	OH	412500N	815100W	50.0	8.58			26.19	-135.	-136.	3.88			-14.52		
131.7060	KRG9	DETROIT	MI	421344N	832329W	50.0	7.24			24.70	-134.	-135.	4.85			-13.35		
131.7060	KAN5	MINNEAPOLIS	MN	445100N	931400W	50.0	-.35			16.81	-134.	-135.	11.07	-138.	-139.	-6.35		
131.7060	WBA2	PIERRE	SD	442300N	1001700W	50.0	-5.26			12.28	-134.	-135.	16.03	-138.	-139.	-1.36		
131.7060	WHU4	PITTSBURG	PA	402934N	801132W	50.0	10.09	-137.	-138.	27.87	-135.	-136.	2.81			-15.81		
131.7500	KID8	ALBANY	GA	313200N	841100W	50.0	9.08			30.19	-137.	-138.	7.65			-13.41		
131.7500	WIJ3	ANNISTON	AL	333500N	855100W	50.0	7.26			27.81	-137.	-138.	8.65			-11.96		
131.7500	KIJ2	ATHENS	GA	335700N	831930W	50.0	9.30			29.59	-137.	-138.	6.47			-13.98		
131.7500	KID4	ATLANTA	GA	333900N	842500W	50.0	8.45			28.90	-137.	-138.	7.45			-13.11		
131.7500	WKW5	BATON ROUGE	LA	303100N	91 840W	10.0	3.26			24.87	-144.	-138.	13.86	-145.	-139.	-7.64		
131.7500	KID3	BIRMINGHAM	AL	333400N	864500W	50.0	6.52			27.11	-137.	-138.	9.41			-11.24		
131.7500	WIV9	BRISTOL	TN	362900N	822400W	50.0	9.45			28.84	-137.	-138.	5.26			-14.52		
131.7500	KRZ5	CHANTILLY	VA	385700N	772700W	10.0	12.63	-144.	-138.	30.68	-143.	-137.	.96			-18.00		
131.7500	WJN2	CHARLESTON	SC	325400N	80 200W	50.0	12.29	-138.	-139.	32.72	-137.	-138.	3.91			-16.68		
131.7500	WBP3	CHATTANOOGA	TN	35 200N	851200W	10.0	7.51			27.56	-144.	-138.	7.81			-12.42		
131.7500	WJZ3	CHICAGO	IL	414700N	674500W	10.0	4.13			22.06	-142.	-136.	8.16			-10.23		
131.7500	WJM9	COLUMBIA	SC	335700N	81 700W	10.0	11.12	-145.	-139.	31.28	-144.	-138.	4.65			-15.73		
131.7500	KKC9	COLUMBUS	MS	332600N	883500W	10.0	5.01			25.70	-144.	-138.	10.97	-145.	-139.	-9.75		
131.7500	KIC6	COLUMBUS	GA	323045N	845630W	50.0	8.25			29.09	-137.	-138.	8.10			-12.75		
131.7500	KJM6	DOTHAN	AL	311908N	852717W	10.0	8.03			29.27	-144.	-138.	8.78			-12.38		
131.7500	KIC7	GADSDEN	AL	335800N	86 600W	50.0	6.98			27.42	-137.	-138.	8.78			-11.75		
131.7500	KKS9	GREENVILLE	MS	332851N	905922W	50.0	3.00			23.75	-137.	-138.	12.97	-138.	-139.	-7.79		
131.7500	WLK3	GREENWOOD	MS	332930N	90 447W	10.0	3.77			24.49	-144.	-138.	12.20	-145.	-139.	-8.54		
131.7500	KUN7	GREER	SC	345348N	821304W	50.0	9.99			29.91	-137.	-138.	5.40			-14.78		
131.7500	KLE4	GULFPORT	MS	302400N	89 300W	10.0	5.08			26.68	-144.	-138.	12.08	-145.	-139.	-9.40		
131.7500	WIJ4	HUNTSVILLE	AL	343819N	864625W	50.0	6.31			26.56	-137.	-138.	9.18			-11.19		
131.7500	KUG9	JACKSON	TN	353600N	685500W	10.0	4.38			24.41	-144.	-138.	10.71	-145.	-139.	-9.46		
131.7500	KKG8	JACKSON	MS	321840N	90 433W	50.0	3.94			25.01	-137.	-138.	12.50	-138.	-139.	-8.54		
131.7500	KIC8	JACKSONVILLE	FL	302916N	814120W	50.0	11.45	-138.	-139.	32.78	-137.	-138.	5.67			-15.54		
131.7500	WIV8	KNOXVILLE	TN	354841N	835946W	50.0	8.34			28.06	-137.	-138.	6.66			-13.34		
131.7500	KMM7	LAUREL-HATTIE\BURG	MS	312800N	892000W	10.0	4.68			25.98	-144.	-138.	12.08	-145.	-139.	-9.15		
131.7500	KPX2	LOS ANGELES	CA	335646N	1182415W	10.0	-19.26			.94			34.62	-144.	-138.	14.84	-145.	-139.
131.7500	KID2	MEMPHIS	TN	35 400N	895800W	50.0	3.61			23.84	-137.	-138.	11.70	-138.	-139.	-8.62		
131.7500	KKN4	MERIDAN	MS	322000N	884500W	10.0	5.05			26.08	-144.	-138.	11.37	-145.	-139.	-9.63		
131.7500	WEX4	MIAMI	FL	254700N	801700W	10.0	13.70	-145.	-139.	36.42	-144.	-138.	5.07			-17.05		
131.7500	KIE2	MOBILE	AL	304105N	881400W	50.0	5.74			27.25	-137.	-138.	11.31	-138.	-139.	-10.08		
131.7500	KLS6	MONROE	LA	323100N	92 200W	50.0	2.25			23.29	-137.	-138.	14.11	-138.	-139.	-6.92		
131.7500	WRY6	MONTGOMERY	AL	321800N	862300W	10.0	7.06			28.02	-144.	-138.	9.37			-11.57		
131.7500	VTR6	MONTREAL	QU	452849N	733228W	30.0	13.03	-135.	-134.	28.14	-135.	-133.	-2.71			-19.65		
131.7500	KID5	MOULTRIE	GA	31 500N	834800W	10.0	9.50			30.74	-144.	-138.	7.40			-13.75		
131.7500	WIV3	MUSCLE SHOALS	AL	344400N	873700W	10.0	5.59			25.85	-144.	-138.	9.86			-10.51		

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FREQ IN MHZ	CALL LETTERS	CITY	STATE OR PROVINCE	LATITUDE	LONGITUDE	TRANSMITTER POWER IN WATTS	SATELLITE AT 15 DEG W ELEV ANGLE IN DEG	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 40 DEG W ELEV ANGLE IN DEG	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 155 DEG W ELEV ANGLE IN DEG	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 180 DEG W ELEV ANGLE IN DEG	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW ACFT
131.7500	WIV4	NASHVILLE	TN	36 700N	864100W	50.0	6.09			25.86	-137.	-138.	8.78			-11.21		
131.7500	KKS6	NATCHEZ	MS	313630N	911730W	50.0	3.00			24.30	-137.	-138.	13.71	-138.	-139.	-7.53		
131.7500	WKV4	NEW ORLEANS	LA	295900N	901500W	50.0	4.10			25.84	-137.	-138.	13.22	-138.	-139.	-8.39		
131.7500	KZR4	NEW YORK	NY	404700N	735200W	10.0	14.67	-143.	-137.	31.58	-142.	-136.	-1.98			-20.30		
131.7500	WIX9	ORLANDO	FL	282600N	811900W	10.0	12.22	-145.	-139.	34.17	-144.	-138.	5.65			-15.99		
131.7500	VCY8	OTTOWA	ON	452722N	753847W	30.0	11.64	-136.	-134.	27.05	-135.	-133.	-1.25			-18.28		
131.7500	WLU8	OXFORD	MS	342300N	893200W	50.0	4.07			24.50	-137.	-138.	11.52	-138.	-139.	-8.97		
131.7500	KJN7	PANAMA CITY	FL	301200N	854100W	10.0	8.03			29.61	-144.	-138.	9.19			-12.23		
131.7500	WDD5	PASCAGOULA	MS	302200N	882900W	10.0	5.58			27.18	-144.	-138.	11.59	-145.	-139.	-9.87		
131.7500	WDB4	ST LOUIS	MO	384500N	902200W	10.0	2.71			21.79	-144.	-138.	10.99	-145.	-139.	-8.32		
131.7500	WIX8	TALLAHASSE	FL	302400N	842100W	10.0	9.15			30.63	-144.	-138.	8.00			-13.33		
131.7500	KKR6	TUPELO	MS	341540N	884810W	50.0	4.70			25.15	-137.	-138.	10.95	-138.	-139.	-9.57		
131.7500	KID6	TUSCALOOSA	AL	331330N	873630W	50.0	5.87			26.60	-137.	-138.	10.20	-138.	-139.	-10.56		
131.7500	KID7	VALDOSTA	GA	304645N	831645W	10.0	10.02	-145.	-139.	31.34	-144.	-138.	7.00			-14.21		
131.7500	KJX7	VALPARAISO	FL	302900N	863100W	50.0	7.26			28.78	-137.	-138.	9.86			-11.52		
131.7500	WST4	YPSILANTI	MI	421400N	833200W	50.0	7.12			24.59	-134.	-135.	4.95			-13.24		
131.7920	WDE3	ALBANY	NY	423720N	74 035W	200.0	13.86	-129.	-136.	30.10	-128.	-135.	-2.08			-19.88		
131.7920	WMI9	FAIRFIELD	CA	381640N	1215800W	50.0	-21.31			-2.36			33.97	-137.	-138.	16.22	-138.	-139.
131.7920	KPY3	MILES CITY	MT	462645N	1055310W	50.0	-9.16			7.77			18.58	-138.	-139.	2.19		
131.7920	WOO2	PORTLAND	OR	453502N	1224700W	50.0	-20.46			-3.61			28.70	-137.	-138.	13.83	-138.	-139.
131.7920	WAS7	SIOUX FALLS	SD	433520N	964600W	50.0	-2.70			15.02	-134.	-135.	13.99	-138.	-139.	-3.78		
131.7960	WON8	MEDFORD	OR	422200N	1225200W	50.0	-21.18			-3.39			31.32	-137.	-138.	15.25	-138.	-139.
131.8000	WLL7	AGANA	GU	132900N	1444800E	10.0	-68.96			-77.58			20.76	-144.	-138.	46.65	-144.	-138.
131.8000	KEY2	ALTONA	NY	444700N	733900W	50.0	13.24	-134.	-135.	28.61	-133.	-134.	-2.55			-19.71		
131.8000	KZT7	BOSTON	MA	422200N	71 000W	50.0	16.08	-135.	-136.	31.95	-134.	-135.	-4.24			-21.98		
131.8000	KOH7	BOSEMAN	MT	454630N	111 930W	4.4	-12.74			4.38			22.16	-148.	-138.	5.93		
131.8000	KFV7	BUFFALO	NY	425450N	784130W	500.0	10.43	-125.	-136.	27.17	-124.	-135.	1.29			-16.59		
131.8000	KPU7	CHICAGO	IL	415900N	875400W	10.0	3.98			21.85	-142.	-136.	8.21			-10.12		
131.8000	WGX2	COLUMBIA	SC	335600N	81 700W	50.0	11.13	-138.	-139.	31.29	-137.	-138.	4.65			-15.73		
131.8000	KIW2	DENVER	CO	394457N	1044819W	50.0	-8.42			10.59	-137.	-138.	21.40	-137.	-138.	2.64		
131.8000	WOK3	HONOLULU	HI	212000N	1575700W	10.0	-53.19			-33.13			64.80	-143.	-137.	54.67	-144.	-138.
131.8000	WOK6	LAKEVIEW	OR	42 930N	1202415W	50.0	-19.52			-1.56			30.10	-137.	-138.	13.59	-138.	-139.
131.8000	WED4	LOS ANGELES	CA	335600N	1182400W	10.0	-19.26			.94			34.62	-144.	-138.	14.84	-145.	-139.
131.8000	WAW6	MINNEAPOLIS	MN	445130N	931300W	50.0	-.34			16.83	-134.	-135.	11.06	-138.	-139.	-6.36		
131.8000	KEA5	NEW YORK	NY	404710N	73 600W	50.0	15.23	-136.	-137.	32.03	-135.	-136.	-2.56			-20.84		
131.8000	WDP8	ONTARIO	CA	34 300N	1172600W	10.0	-18.49			1.72			33.84	-144.	-138.	14.01	-145.	-139.
131.8000	WLU6	OPA LOCKA	FL	255400N	801700W	10.0	13.68	-145.	-139.	36.36	-144.	-138.	5.06			-17.04		
131.8000	KTO9	PHOENIX	AZ	332600N	112 100W	10.0	-14.25			6.32			30.11	-144.	-138.	9.66		
131.8000	WDA3	PROVIDENCE	RI	414330N	712345W	10.0	16.09	-142.	-136.	32.27	-142.	-136.	-3.91			-21.85		
131.8000	WAL9	RAPID CITY	SD	44 215N	103 300W	50.0	-7.20			10.49	-134.	-135.	18.04	-138.	-139.	.65		
131.8000	WMI8	REDDING	CA	403652N	1222030W	50.0	-21.15			-2.84			32.40	-137.	-138.	15.59	-138.	-139.
131.8000	WDS4	ROCHESTER	NY	43 710N	774018W	10.0	11.08	-142.	-136.	27.62	-141.	-135.	.52			-17.27		
131.8000	WFO7	SEATTLE	WA	472620N	1222030W	50.0	-19.78			-3.48			26.98	-137.	-138.	12.74	-138.	-139.
131.8000	VFU	VANCOUVER	BC	491115N	123 915W	50.0	-19.90			-4.17			25.92	-137.	-138.	12.46	-138.	-139.
131.8040	KFC2	BINGHAMTON	NY	421200N	755900W	50.0	12.60	-135.	-136.	29.28	-134.	-135.	-.58			-18.57		
131.8040	KOJ6	EUGENE	OR	44 700N	1231300W	50.0	-21.05			-3.79			30.10	-137.	-138.	14.76	-138.	-139.
131.8040	WMJ4	SAN FRANCISCO	CA	373700N	1222300W	50.0	-21.73			-2.63			34.72	-137.	-138.	16.78	-138.	-139.
131.8080	KPZ7	BILLINGS	MT	454800N	1083200W	50.0	-10.97			6.16			20.57	-138.	-139.	4.13		
131.8080	KTE7	CUDAHY	WI	425645N	875220W	51.0	3.81			21.35	-134.	-135.	7.92			-10.12		
131.8080	WAN9	EAST GRAND FORKS	MN	475454N	97 006W	50.0	-3.30			12.97	-132.	-133.	12.32	-138.	-139.	-3.98		
131.8080	KNQ3	EUREKA	CA	404800N	124 640W	50.0	-22.35			-4.18			33.25	-137.	-138.	16.79	-138.	-139.
131.8080	KDD6	HARTFORD	CT	415600N	724028W	50.0	15.08	-135.	-136.	31.38	-135.	-136.	-2.98			-20.92		
131.8080	KOW7	SALEM	OR	445500N	123 100W	50.0	-20.75			-3.71			29.35	-137.	-138.	14.28	-138.	-139.

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FREQ IN MHZ	CALL LETTERS	CITY	STATE OR PROVINCE	LATITUDE	LONGITUDE	TRANSMITTER POWER IN WATTS	SATELLITE AT 15 DEG W			SATELLITE AT 40 DEG W			SATELLITE AT 155 DEG W			SATELLITE AT 180 DEG W		
							ELEV ANGLE IN DEG	RECEIVED POWER IN DBW		ELEV ANGLE IN DEG	RECEIVED POWER IN DBW		ELEV ANGLE IN DEG	RECEIVED POWER IN DBW		ELEV ANGLE IN DEG	RECEIVED POWER IN DBW	
								GROUND	ACFT		GROUND	ACFT		GROUND	ACFT		GROUND	ACFT
131.8445	WFB5	ATLANTA	GA	333900N	842600W	10.0	8.43			28.89	-144.	-138.	7.46			-13.10		
131.8445	KKF4	JACKSON	MS	321900N	90 500W	50.0	3.92			24.99	-137.	-138.	12.51	-138.	-139.	-8.53		
131.8445	KKG7	LITTLE ROCK	AR	344400N	921400W	50.0	1.80			22.20	-137.	-138.	13.64	-138.	-139.	-6.80		
131.8445	WKV7	NEW ORLEANS	LA	295900N	901500W	50.0	4.10			25.84	-137.	-138.	13.22	-138.	-139.	-8.39		
131.8500	KKC8	ALEXANDRIA	LA	312348N	921743W	50.0	2.17			23.54	-137.	-138.	14.63	-138.	-139.	-6.69		
131.8500	KDV7	ARLINGTON	VA	385100N	77 200W	10.0	12.98	-144.	-138.	31.02	-143.	-137.	.65			-18.32		
131.8500	KUU8	BOSTON	MA	422200N	71 000W	10.0	16.08	-142.	-136.	31.95	-141.	-135.	-4.24			-21.98		
131.8500	KUF9	DETROIT	MI	421300N	832100W	10.0	7.26			24.72	-141.	-135.	4.82			-13.38		
131.8500	KOX4	FAIRFIELD	CA	381600N	1215600W	10.0	-21.29			-2.34			33.95	-144.	-138.	16.19	-145.	-139.
131.8500	WOX4	FT LAUDERDALE	FL	26 400N	80 900W	10.0	13.77	-145.	-139.	36.40	-144.	-138.	4.92			-17.15		
131.8500	WLO5	HOUSTON	TX	293805N	951616W	200.0	-.21			21.63	-131.	-138.	17.70	-132.	-139.	-4.10		
131.8500	KCA3	HYANNIS	MA	413940N	701630W	10.0	16.91	-142.	-136.	32.93	-142.	-136.	-4.73			-22.63		
131.8500	KO69	KEENE	NH	425400N	721600W	10.0	14.96	-142.	-136.	30.84	-141.	-135.	-3.36			-21.01		
131.8500	WLO9	LA CROSSE	WI	435300N	911500W	55.0	1.20			18.60	-134.	-135.	10.03	-138.	-139.	-7.71		
131.8500	KCH8	LEBANON	NH	433700N	721800W	10.0	14.64	-141.	-135.	30.25	-141.	-135.	-3.40			-20.84		
131.8500	WFN6	LOUISVILLE	KY	381100N	854400W	10.0	6.42			25.45	-144.	-138.	7.54			-11.86		
131.8500	KCK5	MARTHAS VINEYARD	MA	412330N	703700W	10.0	16.77	-142.	-136.	32.95	-142.	-136.	-4.45			-22.45		
131.8500	KC16	NANTUCKET	MA	411517N	70 400W	10.0	17.23	-142.	-136.	33.36	-142.	-136.	-4.85			-22.86		
131.8500	KUV3	NEW YORK	NY	403800N	734600W	10.0	14.80	-143.	-137.	31.75	-142.	-136.	-2.04			-20.39		
131.8500	KUW6	NEW YORK	NY	404600N	735200W	10.0	14.67	-143.	-137.	31.59	-142.	-136.	-1.98			-20.30		
131.8500	WPN2	NEWARK	NJ	404200N	741000W	6.5	14.48	-145.	-137.	31.47	-144.	-136.	-1.75			-20.10		
131.8500	WSQ8	PHILADELPHIA	PA	395212N	751754W	6.5	13.95	-146.	-138.	31.41	-145.	-137.	-.82			-19.44		
131.8500	WGI3	PORTLAND	ME	433900N	701800W	10.0	16.00	-141.	-135.	31.26	-140.	-134.	-4.83			-22.17		
131.8500	KCE6	ROCKALDN	ME	44 330N	69 625W	10.0	16.62	-141.	-135.	31.52	-140.	-134.	-5.70			-22.86		
131.8500	WN66	SEATTLE	WA	472709N	1221810W	10.0	-19.76			-3.45			26.95	-144.	-138.	12.71	-145.	-139.
131.8500	WKR5	SHREVEPORT	LA	322723N	935313W	50.0	.70			21.78	-137.	-138.	15.69	-138.	-139.	-5.38		
131.8570	WBA5	SPRINGFIELD	MO	371420N	932200W	50.0	.57			20.23	-138.	-139.	13.79	-138.	-139.	-5.97		
131.8500	WJC2	VAN NUYS	CA	341200N	1182900W	10.0	-19.29			.84			34.51	-144.	-138.	14.83	-145.	-139.
131.8570	WWB7	BATON ROUGE	LA	303200N	91 900W	10.0	3.25			24.84	-144.	-138.	13.87	-145.	-139.	-7.63		
131.8570	KBA4	KANSAS CITY	MO	391825N	944320W	50.0	-.72			18.33	-136.	-137.	14.13	-138.	-139.	-5.01		
131.8570	KIE9	MEMPHIS	TN	35 300N	895800W	50.0	3.61			23.85	-137.	-138.	11.70	-138.	-139.	-8.62		
131.8570	KKF6	MONROE	LA	323036N	92 236W	50.0	2.25			23.30	-137.	-138.	14.11	-138.	-139.	-6.92		

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							SATELLITE AT 15 DEG W			SATELLITE AT 40 DEG W			SATELLITE AT 155 DEG W			SATELLITE AT 180 DEG W		
FREQ IN MHZ	CALL LETTERS	CITY	STATE OR PROVINCE	LATITUDE	LONGITUDE	TRANSMITTER POWER IN WATTS	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT	ELEV ANGLE IN DEG	RECEIVED POWER IN DBW GROUND	ACFT
131.8940	WOH4	GREAT FALLS	MT	472900N	1112200W	50.0	-12.75			3.82			21.19	-137.	-138.	5.60		
131.8940	KAN5	MINNEAPOLIS	MN	445100N	931400W	50.0	-.35			16.81	-134.	-135.	11.07	-138.	-139.	-6.35		
131.8940	WBM2	ROCHESTER	MN	435718N	922634W	50.0	.35			17.79	-134.	-135.	10.84	-138.	-139.	-6.88		
131.8945	KCC8	BANGOR	ME	444800N	684900W	200.0	16.46	-128.	-135.	31.02	-127.	-134.	-5.94			-22.86		
131.8945	WJZ7	BURLINGTON	VT	442800N	73 900W	200.0	13.71	-128.	-135.	29.13	-127.	-134.	-2.87			-20.10		
131.8945	KCT7	MT. WASHINGTON	NH	441613N	711813W	200.0	15.04	-128.	-135.	30.25	-127.	-134.	-4.16			-21.37		
131.8945	KHE4	PHILADELPHIA	PA	395215N	751515W	50.0	13.98	-137.	-138.	31.43	-136.	-137.	-.84			-19.46		
131.8945	KJQ2	TAMPA	FL	275831N	823155W	50.0	11.24	-138.	-139.	33.39	-137.	-138.	6.78			-15.00		
131.9000	WWD6	AGANA	GU	132915N	1444753E	10.0	-68.95			-77.59			20.75	-144.	-138.	46.64	-144.	-138.
131.9000	WRJ7	ARLINGTON	VA	385100N	77 200W	10.0	12.98	-144.	-138.	31.02	-143.	-137.	.65			-18.32		
131.9000	WDV6	BIRMINGHAM	AL	333400N	864500W	6.5	6.52			27.11	-146.	-138.	9.41			-11.24		
131.9000	KCY4	BOSTON	MA	422200N	71 000W	200.0	16.08	-129.	-136.	31.95	-128.	-135.	-4.24			-21.98		
131.9000	KOH7	BOZEMAN	MT	454630N	111 930W	4.4	-12.74			4.38			22.16	-148.	-138.	5.93		
131.9000	KHE8	BUTTE	MT	455700N	1122900W	6.5	-13.62			3.43			22.83	-146.	-138.	6.79		
131.9000	KSH3	CHICAGO	IL	415843N	875421W	50.0	3.98			21.86	-135.	-136.	8.22			-10.12		
131.9000	KLR2	CHICAGO	IL	414700N	874500W	50.0	4.13			22.06	-135.	-136.	8.16			-10.23		
131.9000	KAY7	CLEVELAND	OH	412400N	815000W	10.0	8.60			26.21	-142.	-136.	3.87			-14.53		
131.9000	WDH6	COLLEGE STATION	TX	303500N	962200W	10.0	-1.24			20.36	-145.	-139.	18.37	-145.	-139.	-3.20		
131.9000	WWH8	DALLAS-FT.WORTH	TX	325400N	97 700W	10.0	-2.05			18.92	-145.	-139.	18.26	-145.	-139.	-2.72		
131.9000	WEX2	DUNCAN	OK	342800N	975800W	5.0	-2.86			17.68	-148.	-139.	18.41	-148.	-139.	-2.13		
131.9000	KYB7	FT LAUDERDALE	FL	26 420N	80 925W	50.0	13.77	-138.	-139.	36.40	-137.	-138.	4.92			-17.15		
131.9000	WNS4	FULLERTON	CA	335200N	1175800W	5.0	-18.93			1.30			34.35	-147.	-138.	14.50	-148.	-139.
131.9000	WST6	HOUSTON	TX	295800N	952000W	10.0	-.30			21.46	-144.	-138.	17.66	-145.	-139.	-4.06		
131.9000	KCA3	HYANNIS	MA	413940N	701630W	10.0	16.91	-142.	-136.	32.93	-142.	-136.	-4.73			-22.63		
131.9000	KIG6	JACKSONVILLE	FL	302914N	814101W	200.0	11.45	-132.	-139.	32.78	-131.	-138.	5.67			-15.54		
131.9000	KMC5	LOS ANGELES	CA	355600N	1182400W	10.0	-19.00			.70			33.29	-144.	-138.	14.22	-145.	-139.
131.9000	KJS4	MC FARLAND	CA	353910N	119 815W	5.0	-19.60			.14			33.99	-147.	-138.	14.90	-148.	-139.
131.9000	KOM2	MISSOULA	MT	465414N	114 500W	50.0	-14.58			2.14			23.10	-137.	-138.	7.57		
131.9000	KFK4	NEW YORK	NY	403800N	734600W	200.0	14.80	-130.	-137.	31.75	-129.	-136.	-2.04			-20.39		
131.9000	KUI4	ONTARIO	CA	34 300N	1173600W	10.0	-18.62			1.58			33.96	-144.	-138.	14.14	-145.	-139.
131.9000	KVV2	OXNARD	CA	341200N	1191200W	10.0	-19.85			.25			35.02	-144.	-138.	15.42	-145.	-139.
131.9000	WOS5	RIVERSIDE	CA	335700N	1172700W	5.0	-18.51			1.72			33.92	-147.	-138.	14.05	-148.	-139.
131.9000	KDL5	ROCHESTER	NY	43 940N	773820W	50.0	11.09	-135.	-136.	27.62	-134.	-135.	.49			-17.29		
131.9000	KCE6	ROCKLAND	ME	44 330N	69 625W	10.0	16.62	-141.	-135.	31.52	-140.	-134.	-5.70			-22.86		
131.9000	WLL9	SAN FRANCISCO	CA	373700N	1222300W	10.0	-21.73			-2.63			34.72	-144.	-138.	16.78	-145.	-139.
131.9000	KZY6	SANTA ANA	CA	334000N	1175200W	10.0	-18.87			1.41			34.41	-144.	-138.	14.48	-145.	-139.
131.9000	KOH6	SPOKANE	WA	473800N	1173200W	50.0	-16.71			-.30			24.43	-137.	-138.	9.58		
131.9000	KJP2	WASHINGTON	DC	385044N	77 007W	200.0	13.01	-131.	-138.	31.05	-130.	-137.	.63			-18.34		
131.9000	WEN5	WILMINGTON	NC	341612N	775443W	200.0	13.70	-132.	-139.	33.48	-131.	-138.	1.94			-18.23		
131.9000	WSF2	WINDSOR LOCKS	CT	415500N	724100W	10.0	15.08	-142.	-136.	31.39	-142.	-136.	-2.97			-20.91		
131.9060	KOM3	HELENA	MT	463627N	1115945W	50.0	-13.23			3.62			22.11	-137.	-138.	6.26		
131.9060	KSH4	MADISON	WI	43 824N	891939W	50.0	2.72			20.28	-134.	-135.	8.90			-9.08		
131.9060	KTI6	MILWAUKEE	WI	425654N	875407W	50.0	3.78			21.33	-134.	-135.	7.95			-10.10		
131.9060	CYD	MONTREAL	QU	452734N	735032W	50.0	12.84	-133.	-134.	28.00	-132.	-133.	-2.50			-19.46		
131.9060	KOI8	PORTLAND	OR	452720N	1223205W	50.0	-20.32			-3.42			28.68	-137.	-138.	13.72	-138.	-139.
131.9060	WF06	SEATTLE	WA	472700N	1221800W	50.0	-19.76			-3.45			26.95	-137.	-138.	12.71	-138.	-139.
131.9060	KOC9	SEATTLE	WA	484226N	1222349W	200.0	-19.54			-3.63			25.97	-131.	-138.	12.21	-132.	-139.
131.9070	KFH4	NEW YORK	NY	404128N	735318W	200.0	14.69	-130.	-137.	31.65	-129.	-136.	-1.96			-20.30		
131.9070	KCJ9	PRESQUE ISLAND	ME	464100N	68 300W	10.0	16.03	-139.	-133.	29.74	-139.	-133.	-6.54			-22.87		

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FREQ IN MHZ	CALL LETTERS	CITY	STATE OR PROVINCE	LATITUDE	LONGITUDE	TRANSMITTER POWER IN WATTS	SATELLITE AT 15 DEG W ELEV ANGLE IN DEG	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 40 DEG W ELEV ANGLE IN DEG	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 155 DEG W ELEV ANGLE IN DEG	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 180 DEG W ELEV ANGLE IN DEG	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW ACFT
131.9500	WAC5	ALEXANDRIA	MN	455220N	952335W	5.0	-1.98			14.93	-143.	-134.	12.13	-148.	-139.	-4.91		
131.9500	KVM8	ALLENTOWN	PA	403820N	752645W	10.0	13.57	-143.	-137.	30.75	-142.	-136.	-.79			-19.21		
131.9500	KIF2	ATLANTA	GA	333922N	842600W	50.0	8.43			28.89	-137.	-138.	7.46			-13.10		
131.9500	WRT9	CHANTILLY	VA	385700N	772700W	5.0	12.63	-147.	-136.	30.68	-146.	-137.	.96			-18.00		
131.9500	WRR7	CHARLOTTE	NC	351300N	805600W	5.0	10.95	-148.	-139.	30.66	-147.	-138.	4.29			-15.76		
131.9500	WNO7	CHARLOTTESVILLE	VA	38 800N	782700W	10.0	12.11	-145.	-139.	30.57	-143.	-137.	1.85			-17.36		
131.9500	KXT3	CHICAGO	IL	414600N	874630W	10.0	4.12			22.06	-142.	-136.	8.17			-10.22		
131.9500	KZJ3	CLEAR LAKE CITY	TX	293320N	95 125W	10.0	.01			21.88	-144.	-138.	17.51	-145.	-139.	-4.31		
131.9500	WSR8	CLEVELAND	OH	412400N	815030W	10.0	8.60			26.21	-142.	-136.	3.87			-14.53		
131.9500	WBP5	COVINGTON	KY	39 300N	844000W	10.0	7.06			25.72	-143.	-137.	6.52			-12.62		
131.9500	KYB3	DALLAS	TX	325100N	965100W	6.5	-1.82			19.16	-146.	-139.	18.05	-147.	-139.	-2.93		
131.9500	KVO9	DAVENPORT	IA	413600N	903500W	6.5	2.07			20.22	-144.	-136.	10.29	-147.	-139.	-6.17		
131.9500	WKV8	DENVER	CO	394600N	1045300W	10.0	-8.48			10.52	-144.	-138.	21.45	-144.	-138.	2.70		
131.9500	KJH3	DUBUQUE	IA	422400N	904300W	10.0	1.84			19.72	-142.	-136.	10.13	-145.	-139.	-8.08		
131.9500	WNK5	ELMIRA	NY	421000N	765400W	8.0	11.96	-143.	-136.	28.76	-142.	-135.	.10			-17.94		
131.9500	WAE4	FT WASHINGTON	PA	40 620N	751230W	10.0	13.92	-143.	-137.	31.26	-142.	-136.	-.91			-19.46		
131.9500	KDE8	GALVELSTON	TX	291600N	945200W	5.0	.16			22.11	-147.	-138.	17.46	-148.	-139.	-4.43		
131.9500	WNX7	GRANBY	CO	40 500N	1055500W	5.0	-9.25			9.65			22.02	-147.	-138.	3.43		
131.9500	KKX5	LACROSSE	WI	435300N	911500W	10.0	1.20			18.60	-141.	-135.	10.03	-145.	-139.	-7.71		
131.9500	KRQ7	LAKE JACKSON	TX	29 210N	952712W	10.0	-.32			21.68	-144.	-138.	18.04	-145.	-139.	-3.91		
131.9500	KEQ3	LONGVIEW	TX	322300N	944300W	.5	.01			21.11	-157.	-138.	16.41	-158.	-139.	-4.68		
131.9500	WAW4	MOSES LAKE	WA	471200N	1191900W	5.0	-17.92			-1.43			25.67	-147.	-138.	10.90	-148.	-139.
131.9500	KHP3	MOSES LAKE	WA	471200N	1191900W	5.0	-17.92			-1.43			25.67	-147.	-138.	10.90	-148.	-139.
131.9500	KIX6	NEW YORK	NY	404400N	74 000W	50.0	14.59	-136.	-137.	31.54	-135.	-136.	-1.88			-20.21		
131.9500	KHK2	PITTSBURG	PA	402100N	795600W	10.0	10.31	-144.	-138.	28.12	-142.	-136.	2.64			-16.01		
131.9500	KLG2	STEAMBOAT SPRINGS	CO	402726N	1064423W	10.0	-9.86			8.93			22.40	-144.	-138.	3.98		
131.9500	WNU3	TETERBORO	NJ	405100N	74 400W	10.0	14.49	-143.	-137.	31.41	-142.	-136.	-1.84			-20.14		
131.9500	KEL8	TYLER	TX	322100N	952400W	6.5	-.57			20.55	-146.	-139.	17.00	-147.	-139.	-4.11		
131.9500	WFZ3	VICTORIA	TX	285100N	965500W	5.0	-1.59			20.44	-148.	-139.	19.39	-148.	-139.	-2.63		
131.9500	WSB2	WESTFIELD	MA	42 900N	724400W	10.0	14.94	-142.	-136.	31.18	-141.	-135.	-2.95			-20.83		
131.9500	WCL9	WILLMAR	MN	45 700N	95 500W	5.0	-1.68			15.47	-143.	-134.	12.22	-148.	-139.	-5.07		
131.9500	WKK6	WINONA	MN	44 500N	914200W	6.5	.85			18.21	-142.	-134.	10.28	-147.	-139.	-7.40		
131.9500	KQK2	YOUNGSTOWN	OH	411600N	804000W	50.0	9.50			27.05	-135.	-136.	3.03			-15.38		

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FREQ IN MHZ	CALL LETTERS	CITY	STATE OR PROVINCE	LATITUDE	LONGITUDE	TRANSMITTER POWER IN WATTS	SATELLITE AT 15 DEG W ELEV ANGLE IN DEG	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 40 DEG W ELEV ANGLE IN DEG	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 155 DEG W ELEV ANGLE IN DEG	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 180 DEG W ELEV ANGLE IN DEG	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW ACFT
132.0000	KPQ2	ALLENTOWN	PA	403900N	752600W	10.0	13.56	-143.	-137.	30.74	-142.	-136.	-.79			-19.21		
132.0000	WS27	ALTON	IL	385300N	90 300W	6.5	2.93			21.95	-146.	-138.	10.70	-147.	-139.	-8.56		
132.0000	WKQ5	AMELIA	LA	294138N	91 618W	50.0	3.40			25.23	-137.	-138.	14.04	-138.	-139.	-7.66		
132.0000	WFA3	AMERICUS	GA	32 700N	841100W	5.0	8.96			29.89	-147.	-138.	7.54			-13.38		
132.0000	WEI6	ANCHORAGE	AK	611000N	1495900W	10.0	-27.62			-17.75			20.60	-138.	-132.	16.36	-139.	-133.
132.0000	KTY5	APPLETON	WI	441540N	883110W	10.0	3.07			20.19	-140.	-134.	8.00			-9.63		
132.0000	KYC9	ASPEN	CO	39 908N	1064910W	10.0	-9.94			9.22			23.15	-144.	-138.	4.30		
132.0000	KNA5	ATLANTA	GA	333925N	842510W	10.0	8.45			28.90	-144.	-138.	7.45			-13.11		
132.0000	WRP4	BALDWIN	MI	435300N	855100W	6.5	5.04			22.11	-143.	-135.	6.23			-11.51		
132.0000	KPS7	BANGOR	ME	444800N	684900W	10.0	19.06	-140.	-134.	32.82	-140.	-134.	-8.72			-25.42		
132.0000	WPI6	BATTLE CREEK	MI	421900N	851500W	6.5	5.85			23.42	-143.	-135.	6.19			-12.01		
132.0000	KWG3	BEAUFORT	SC	322830N	804300W	5.0	11.82	-148.	-139.	32.45	-147.	-138.	4.55			-16.17		
132.0000	WRP4	BENTON HARBOR	MI	42 800N	862600W	6.5	5.03			22.75	-143.	-135.	7.10			-11.17		
132.0000	WKG7	BLK 154D SHIP SHOAL	LA	284105N	911205W	50.0	3.43			25.53	-137.	-138.	14.37	-138.	-139.	-7.57		
132.0000	WKT4	CAMERON	LA	294640N	932020W	50.0	1.45			23.26	-137.	-138.	15.97	-138.	-139.	-5.76		
132.0000	WBF7	CAMP HILL	PA	401440N	765600W	10.0	12.59	-143.	-137.	30.12	-142.	-136.	.39			-18.20		
132.0000	KPY6	CAPE GIRARDEAU	MO	371338N	893420W	10.0	3.59			23.13	-144.	-138.	10.80	-145.	-139.	-8.93		
132.0000	WHY2	CARBONDALE	IL	374700N	891500W	5.0	3.74			23.09	-147.	-138.	10.39	-148.	-139.	-9.18		
132.0000	KRR4	CENTRALIA	IL	383100N	89 500W	6.5	3.74			22.84	-146.	-138.	10.06	-147.	-139.	-9.30		
132.0000	WNC5	CHICAGO	IL	415100N	873600W	6.5	4.23			22.13	-144.	-136.	8.03			-10.34		
132.0000	KLG6	CHICAGO	IL	415843N	875421W	10.0	3.98			21.86	-142.	-136.	8.22			-10.12		
132.0000	WMO4	COATESVILLE	PA	395845N	755130W	50.0	13.50	-137.	-138.	30.98	-136.	-137.	-.40			-19.02		
132.0000	WWZ3	COLUMBUS	OH	40 000N	825230W	10.0	8.20			26.40	-142.	-136.	4.93			-13.90		
132.0000	WQH2	DALLAS	TX	325100N	965100W	10.0	-1.82			19.16	-145.	-139.	18.05	-145.	-139.	-2.93		
132.0000	KKJ5	DALLAS-FT.WORTH	TX	325400N	97 200W	10.0	-1.98			18.99	-145.	-139.	18.19	-145.	-139.	-2.78		
132.0000	KMJ8	DENVER	CO	394600N	1045300W	10.0	-8.48			10.52	-144.	-138.	21.45	-144.	-138.	2.70		
132.0000	WPF3	DETROIT	MI	421300N	832100W	6.5	7.26			24.72	-143.	-135.	4.82			-13.38		
132.0000	KRY7	DETROIT	MI	421400N	833200W	50.0	7.12			24.59	-134.	-135.	4.95			-13.24		
132.0000	KAH9	DODGE CITY	KS	374600N	985800W	50.0	-3.88			15.71	-138.	-139.	17.94	-138.	-139.	-1.61		
132.0000	WQM4	DUBLIN	GA	323400N	825900W	5.0	9.88			30.61	-147.	-138.	6.44			-14.33		
132.0000	WHD9	ELKHART	IN	414300N	855900W	5.0	5.45			23.29	-145.	-136.	6.88			-11.52		
132.0000	KPX4	FLORENCE	SC	34 958N	794515W	10.0	12.20	-145.	-139.	32.19	-144.	-138.	3.49			-16.79		
132.0000	KNJ7	FT LAUDERDALE	FL	26 400N	80 900W	10.0	13.77	-145.	-139.	36.40	-144.	-138.	4.92			-17.15		
132.0000	WOZ2	GALVESTON	TX	291935N	944616W	50.0	.25			22.18	-137.	-138.	17.35	-138.	-139.	-4.51		
132.0000	WOY4	GARDINA	CA	335123N	1181635W	10.0	-19.17			1.06			34.58	-144.	-138.	14.75	-145.	-139.
132.0000	KAQ9	GREAT BEND	KS	382018N	905042W	10.0	2.41			21.64	-144.	-138.	11.47	-145.	-139.	-7.96		
132.0000	KBL2	HAILEY	ID	433030N	1141830W	10.0	-15.10			2.66			25.53	-144.	-138.	8.78		
132.0000	KTR4	HILTON HEAD ISLAND	SC	321320N	804150W	5.0	11.91	-148.	-139.	32.62	-147.	-138.	4.55			-16.22		
132.0000	WBP2	HOUSTON	TX	30 313N	952606W	20.0	-.39			21.34	-141.	-138.	17.73	-142.	-139.	-3.97		
132.0000	WQK8	INDIANAPOLIS	IN	394200N	861700W	10.0	5.67			24.22	-143.	-137.	7.60			-11.38		
132.0000	WSF4	INTERCOASTAL CITY	LA	294710N	92 838W	50.0	2.49			24.30	-137.	-138.	14.92	-138.	-139.	-6.78		
132.0000	WOL3	JACKSONVILLE	IL	394600N	901400W	5.0	2.64			21.38	-146.	-137.	10.59	-148.	-139.	-8.42		
132.0000	KVF8	KANSAS CITY	MO	391250N	944120W	10.0	-.69			18.39	-143.	-137.	14.14	-145.	-139.	-5.03		

TABLE A-1

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FREQ IN MHZ	CALL LETTERS	CITY	STATE OR PROVINCE	LATITUDE	LONGITUDE	TRANSMITTER POWER IN WATTS	SATELLITE AT 15 DEG W ELEV ANGLE IN DEG	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 15 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 40 DEG W ELEV ANGLE IN DEG	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 40 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 155 DEG W ELEV ANGLE IN DEG	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 155 DEG W RECEIVED POWER IN DBW ACFT	SATELLITE AT 180 DEG W ELEV ANGLE IN DEG	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW GROUND	SATELLITE AT 180 DEG W RECEIVED POWER IN DBW ACFT
132.0000	WJJ8	KILEEN	TX	31 500N	974100W	10.0	-2.40			19.06	-145.	-139.	19.35	-145.	-139.	-2.12		
132.0000	KEN6	KOKOMO	IN	403200N	86 400W	10.0	5.65			23.91	-143.	-137.	7.23			-11.51		
132.0000	KKA5	LAFAYETTE	IN	402400N	865600W	10.0	5.03			23.38	-143.	-137.	7.92			-10.87		
132.0000	WKE5	LAFAYETTE	LA	301232N	915936W	50.0	2.57			24.26	-137.	-138.	14.68	-138.	-139.	-6.92		
132.0000	WJ69	LAS VEGAS	NV	36 500N	115 900W	6.5	-16.49			3.30			30.90	-146.	-138.	11.57	-147.	-139.
132.0000	KTY2	LAS VEGAS	NV	361215N	1151150W	5.0	-16.51			3.26			30.85	-147.	-138.	11.57	-148.	-139.
132.0000	WKJ5	LEEVILLE	LA	291330N	901415W	50.0	4.21			26.16	-137.	-138.	13.39	-138.	-139.	-8.40		
132.0000	KDX7	LONG BEACH	CA	334900N	118 900W	6.5	-19.08			1.16			34.52	-146.	-138.	14.67	-147.	-139.
132.0000	WLV2	LOUISVILLE	KY	381100N	854030W	5.0	6.47			25.50	-147.	-138.	7.49			-11.91		
132.0000	W6H8	MAIN PASS BLK 289B	LA	291531N	882630W	50.0	5.79			27.71	-137.	-138.	11.79	-138.	-139.	-9.93		
132.0000	WDF8	MIAMI	FL	254700N	801000W	10.0	13.81	-145.	-139.	36.52	-144.	-138.	4.96			-17.15		
132.0000	KAX7	MINNEAPOLIS	MN	445300N	931300W	10.0	-.35			16.81	-141.	-135.	11.05	-145.	-139.	-6.36		
132.0000	KL65	MOSINEE	WI	444600N	894000W	10.0	2.16			19.17	-140.	-134.	8.65			-8.83		
132.0000	WEK6	MUSTANG ISLAND	TX	272930N	971600W	50.0	-1.80			20.55	-138.	-139.	20.11	-138.	-139.	-2.25		
132.0000	WKI2	NEW ORLEANS	LA	295637N	901109W	50.0	4.16			25.91	-137.	-138.	13.17	-138.	-139.	-8.44		
132.0000	WDI9	NEW YORK	NY	404600N	735200W	6.5	14.67	-145.	-137.	31.59	-144.	-136.	-1.98			-20.30		
132.0000	KRH2	NORFOLK	VA	365110N	761710W	10.0	14.21	-145.	-139.	32.90	-144.	-138.	.32			-19.15		
132.0000	KAF3	NORTH ADAMS	MA	424200N	731000W	5.0	14.42	-145.	-136.	30.51	-144.	-135.	-2.69			-20.43		
132.0000	KPS8	PHILADELPHIA	PA	395300N	751400W	10.0	13.99	-144.	-138.	31.42	-143.	-137.	-.86			-19.47		
132.0000	WHZ2	PORTLAND	OR	453500N	1223600W	5.0	-20.34			-3.48			28.60	-147.	-138.	13.71	-148.	-139.
132.0000	WJT6	QUINCY	IL	395700N	911200W	6.5	1.88			20.60	-145.	-137.	11.26	-147.	-139.	-7.70		
132.0000	KAI4	SEATTLE	WA	473100N	1223600W	10.0	-19.93			-3.66			27.04	-144.	-138.	12.87	-145.	-139.
132.0000	WFE9	SIKESTON	MO	365300N	893400W	5.0	3.64			23.29	-147.	-138.	10.89	-148.	-139.	-8.94		
132.0000	KHY4	SIOUX CITY	IA	422400N	962300W	2.0	-2.31			15.79	-149.	-136.	14.19	-152.	-139.	-3.96		
132.0000	KRZ7	SMYRNA	TN	36 000N	863100W	10.0	6.25			26.05	-144.	-138.	8.67			-11.34		
132.0000	WAA8	SOUTH MARSH ISLAND	LA	285259N	915345W	50.0	2.81			24.86	-137.	-138.	14.93	-138.	-139.	-6.98		
132.0000	WHZ8	SPRINGFIELD	IL	395100N	894100W	5.5	3.05			21.74	-146.	-137.	10.14	-148.	-139.	-8.83		
132.0000	WKH7	ST LOUIS	MO	383900N	902100W	10.0	2.74			21.85	-144.	-138.	11.00	-145.	-139.	-8.33		
132.0000	WHY5	ST LOUIS	MO	383900N	902100W	5.5	2.74			21.85	-146.	-138.	11.00	-148.	-139.	-8.33		
132.0000	WIM7	ST PETERSBURG	FL	275500N	824100W	10.0	11.10	-145.	-139.	33.27	-144.	-138.	6.94			-14.86		
132.0000	WAF3	ST SIMONS ISLAND	GA	31 900N	812300W	10.0	11.56	-145.	-139.	32.66	-144.	-138.	5.31			-15.73		
132.0000	WQM7	STATESBORO	GA	322900N	814500W	5.5	10.94	-148.	-139.	31.63	-147.	-138.	5.42			-15.34		
132.0000	KAW4	SUFFIELD	OH	41 030N	812130W	20.0	9.07			26.78	-139.	-136.	3.59			-14.92		
132.0000	KIA4	TACOMA	WA	47 900N	1222900W	10.0	-19.93			-3.55			27.28	-144.	-138.	12.95	-145.	-139.
132.0000	WSC2	TETERBORO	NJ	405100N	74 400W	10.0	14.49	-143.	-137.	31.41	-142.	-136.	-1.84			-20.14		
132.0000	KYE6	THOMASVILLE	GA	305400N	835300W	6.5	9.46			30.76	-146.	-138.	7.50			-13.69		
132.0000	WEZ2	TIFTON	GA	312600N	832900W	5.0	9.70			30.81	-147.	-138.	7.07			-13.99		
132.0000	WLC7	VENICE	LA	291550N	892145W	50.0	4.98			26.91	-137.	-138.	12.60	-138.	-139.	-9.15		
132.0000	WLU5	VERMILION BLK 245A	LA	283434N	922638W	100.0	2.36			24.49	-134.	-138.	15.49	-135.	-139.	-6.50		
132.0000	WEF6	VERMILION BLK 76		291719N	922320W	10.0	2.33			24.27	-144.	-138.	15.27	-145.	-139.	-6.56		
132.0000	KIN4	WATCROSS	GA	311500N	822400W	10.0	10.67	-145.	-139.	31.79	-144.	-138.	6.17			-14.89		
132.0000	WRO5	WEST CAMERON BK 543	LA	282040N	822400W	10.0	11.27	-145.	-139.	33.31	-144.	-138.	6.62			-15.08		
132.0000	KBD9	WHITE PLAINS	NY	41 421N	734225W	10.0	14.68	-142.	-136.	31.46	-142.	-136.	-2.14			-20.36		
132.0000	WDZ6	WICHITA	KS	373900N	972500W	10.0	-2.66			16.95	-145.	-139.	16.80	-145.	-139.	-2.82		

APPENDIX B

TRANSMITTERS IN THE US AND CANADA IN THE 125.4 to 126.0 MHz BAND

TABLE B-1 is a list of all the ground-based transmitters in the US and Canada in the 125.4 to 126.0 MHz band. (They all use omni-directional antennas.) The column headings are described below:

FREQUENCY IN MHz - gives the exact carrier frequency of each transmitter. The transmitters are listed by frequency.

STATE OR PROVINCE - ground station location.

CITY - ground station location.

LATITUDE - ground station location.

LONGITUDE - ground station location.

TRANSMITTER POWER IN WATTS - ground station transmitter power.

TABLE B-1

TRANSMITTERS IN THE US AND CANADA IN THE 125.4 TO 126.0 MHz BAND
(Page 1 of 12)

Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.4	AZ	Globe	33 16 56N	110 49 13W	10
125.4	AR	Ft. Smith	35 19 XXN	094 22 XXW	50
125.4	CA	Santbrbr	34 25 47N	119 51 27W	10
125.4	CA	Marysvll	39 06 11N	121 33 52W	10
125.4	FL	Pompnbch	26 14 36N	080 06 51W	10
125.4	GA	Augusta	33 22 30N	081 59 27W	10
125.4	IL	Chicago	41 59 XXN	087 55 XXW	10
125.4	NE	Millard	41 11 46N	096 06 43W	10
125.4	OH	Columbus	39 59 56N	082 54 19W	10
125.4	PA	Flinthll	40 22 XXN	075 21 XXW	50
125.4	TN	Nashvll	36 21 XXN	086 47 XXW	50
125.4	TX	Crpschrs	27 45 53N	097 30 34W	50
125.4	TX	Waco	31 37 13N	097 13 50W	50
125.4	TX	Amarillo	35 10 15N	101 49 35W	10
125.4	UT	Saltl Cy	40 46 27N	111 57 31W	50
125.4	WA	Tacoma	47 09 XXN	122 28 XXW	50
125.4	Manitoba	Winnipg	49 54 00N	97 14 00W	50
125.4	Ontario	Toronto	43 41 00N	79 38 00W	50

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Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.45	CA	San Diego	32 49 15N	116 59 15W	10
125.45	FL	Jcksnvll	30 28 32N	081 39 10W	50
125.45	IL	Quincy	39 56 39N	091 08 56W	50
125.45	MI	Pontiac	42 39 44N	083 25 22W	10
125.45	NY	Albany	42 44 32N	073 49 21W	10
125.5	AL	Montgmry	32 22 XXN	086 24 XXW	50
125.5	CA	Mtn View	37 19 08N	122 08 45W	50
125.5	CA	Ontaria	34 03 15N	117 35 15W	10
125.5	CA	Sacramnt	38 33 14N	121 16 09W	20
125.5	CA	Oakland	37 31 44N	122 25 35W	20
125.5	CA	Oakland	37 32 33N	122 00 53W	20
125.5	FL	Petrsbrg	27 54 23N	082 41 27W	50
125.5	ID	Boise	43 30 34N	116 14 07W	50
125.5	KS	Hutchnsn	38 03 57N	097 52 06W	10
125.5	LA	N Orleans	29 59 XXN	090 15 XXW	50
125.5	MI	Bntnhrbr	42 07 30N	086 25 37W	10
125.5	MN	Darwin	45 05 15N	094 27 12W	50
125.5	MO	St. Louis	38 48 52N	090 23 09W	50

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Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.5	MO	St. Louis	38 42 04N	090 23 26W	20
125.5	NV	Battlmtn	40 24 11N	116 52 02W	20
125.5	NJ	Newark	40 41 XXN	074 09 XXW	50
125.5	NY	Buffalo	42 56 11N	078 44 39W	50
125.5	OH	Akron	40 54 45N	081 26 13W	50
125.5	CZ	Balboa	08 55 36N	079 37 23W	1000
125.5	SC	Greenvll	34 39 XXN	082 07 XXW	50
125.5	TX	Austin	30 17 30N	097 41 55W	10
125.5	VA	Chantlly	38 56 31N	077 25 42W	50
125.5	British Columbia	Comox	49 43 00N	124 54 00W	50
125.5	Ontario	Sudbury	46 38 XXN	080 46 XXW	50
125.5	Quebec	Roberval	48 31 00N	072 17 00W	50
125.55	FL	Orlando	28 32 42N	081 20 29W	50
125.55	NY	Wayland	42 30 XXN	077 37 XXW	50
125.55	OH	Marietta	39 27 44N	081 21 45W	50
125.55	WI	Greenbay	44 20 26N	087 56 48W	50

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Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.6	AL	Huntsvll	34 38 55N	086 46 21W	50
125.6	AZ	Phoenix	33 26 10N	111 59 45W	10
125.6	AR	Littlrck	34 43 48N	092 13 23W	50
125.6	CA	Snfrncsc	37 37 14N	122 21 52W	10
125.6	CA	Torrance	33 48 06N	118 20 21W	10
125.6	CO	Denver	39 45 18N	104 53 54W	10
125.6	FL	Miami	25 47 58N	080 21 07W	50
125.6	IL	Lwrncvll	38 45 XXN	087 36 XXW	10
125.6	MI	Detroit	42 13 XXN	083 22 XXW	10
125.6	MI	Carleton	42 00 12N	083 21 44W	10
125.6	ND	Jamestwn	47 06 24N	099 18 40W	50
125.6	NV	Las Vegas	36 04 45N	115 08 56W	10
125.6	NJ	Shipbttm	39 47 XXN	074 21 XXW	50
125.6	NM	Tucumcar	34 56 15N	103 23 30W	10
125.6	NM	Mesarica	35 14 17N	104 12 14W	20
125.6	NY	NY Cy	40 39 XXN	073 46 XXW	50
125.6	OK	Okla Cy	35 23 16N	097 36 35W	50

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Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.6	TN	Bristol	36 28 30N	082 24 15W	10
125.6	TX	Houston	29 33 27N	095 08 21W	50
125.6	UT	Saltl Cy	40 46 27N	111 57 31W	10
125.6	WA	Ft. Lawton	47 39 22N	122 24 43W	50
125.6	WA	Ft. Lawton	47 39 28N	122 24 43W	20
125.6	WA	Auburn	47 17 16N	122 11 12W	20
125.6	WI	Dells	43 33 03N	089 45 49W	10
125.6	Montreal	Quebec	45 27 00N	073 45 00W	50
125.65	CT	Wndsrlks	41 56 22N	072 40 31W	10
125.65	FA	Gainsvll	29 41 27N	082 16 28W	10
125.65	KY	N Hope	37 37 54N	085 40 33W	50
125.65	MD	Cp Spr	38 48 XXN	076 53 XXW	50
125.65	MI	Gr Rapids	42 52 31N	085 31 46W	10
125.7	AK	Homer	59 40 31N	151 35 08W	50
125.7	AL	Mobile	30 40 54N	088 14 33W	50
125.7	AK	Fire I	61 09 38N	150 19 29W	50
125.7	AR	Texarkan	33 27 24N	093 59 45W	50

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Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.7	CA	Sacramnt	38 41 59N	121 35 33W	10
125.7	CO	Colo Spr	38 49 23N	104 42 07W	10
125.7	GA	Atlanta	33 39 XXN	084 26 XXW	50
125.7	ID	Lewiston	46 22 28N	117 00 53W	10
125.7	IL	Chicago	41 59 XXN	087 55 XXW	10
125.7	KS	Wichita	37 40 XXN	097 26 XXW	50
125.7	MN	Minnepls	45 03 37N	093 20 39W	10
125.7	NE	Omaha	41 07 23N	095 55 03W	10
125.7	NE	Lincoln	40 50 46N	096 46 34W	100
125.7	NY	NY Cy	40 38 46N	073 46 55W	50
125.7	OH	Chardon	41 31 01N	081 09 48W	50
125.7	TX	Sananton	29 32 18N	098 28 01W	50
125.7	UT	Saltl Cy	40 46 43N	111 57 21W	10
125.7	VA	Norfolk	36 53 27N	076 12 35W	50
125.7	VA	Nwprtnws	37 07 58N	076 29 36W	10
125.7	AK	Talkeetn	62 19 53N	150 05 56W	50
125.7	Alberta	Edmonton	53 19 XXN	113 35 XXW	50

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Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.7	Quebec	Montreal	45 27 34N	073 50 32W	50
125.75	FA	Miami	25 47 55N	080 16 50W	50
125.75	IN	So Bend	41 41 55N	086 18 35W	50
125.75	MS	Narchez	31 37 05N	091 17 58W	10
125.75	MO	Kansas Cy	39 17 00N	094 43 34W	10
125.75	NJ	Teterbor	40 50 52N	074 03 10W	10
125.75	VA	Bedford	37 30 51N	079 30 41W	50
125.75	VA	Buenavst	37 47 44N	079 10 51W	50
125.75	Ontario	Killaloe	45 35 52N	077 23 28W	50
125.8	CA	Saddlepk	34 04 33N	118 39 29W	10
125.8	CA	Sanpedro	33 44 44N	118 20 04W	20
125.8	CA	Palmdale	34 36 11N	118 05 04W	20
125.8	CA	Hayward	37 39 31N	122 07 38W	10
125.8	CO	La Junta	37 56 30N	103 10 50W	10
125.8	CO	Denver	39 44 XXN	104 44 XXW	10
125.8	CO	Eastnvll	39 05 06N	104 31 23W	50
125.8	CO	Trinidad	37 32 50N	104 00 49W	20
125.8	CO	Parker	39 35 40N	104 41 34W	20

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Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.8	CN	Woodstck	41 57 XXN	072 13 XXW	50
125.8	FA	Tampa	28 29 XXN	082 23 XXW	50
125.8	ID	Ashton	44 33 41N	111 26 36W	20
125.8	IL	Peoria	40 40 XXN	089 41 XXW	10
125.8	KY	Owensbor	37 44 46N	087 09 40W	10
125.8	MA	Winthrop	42 23 21N	070 58 07W	20
125.8	MN	Duluth	46 50 16N	092 11 23W	10
125.8	MO	Springfield	37 14 38N	093 22 52W	10
125.8	MT	Billings	45 48 37N	108 35 40W	10
125.8	NC	Ashevill	35 26 04N	082 32 04W	10
125.8	NV	Reno	39 31 53N	119 39 18W	10
125.8	NH	Nashua	42 44 10N	071 28 52W	20
125.8	NY	Saratoga	43 00 37N	073 40 57W	20
125.8	OH	Dayton	39 54 01N	084 13 01W	10
125.8	OR	Horton	44 17 01N	123 35 09W	50
125.8	OR	Laurlmtn	44 55 24N	123 34 23W	20
125.8	PR	San Juan	18 26 24N	065 59 53W	10
125.8	SD	Sioxflls	43 36 XXN	096 44 XXW	10

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EMC ANALYSIS OF THE PROPOSED AEROSAT VHF SUBSYSTEM WITH CURRENT--ETC(U)
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TABLE B-1

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Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.8	TN	Memphis	35 04 XXN	089 59 XXW	50
125.8	TX	Ft. Worth	32 49 17N	097 02 06W	50
125.8	TX	Dallas	32 51 18N	096 50 49W	50
125.8	TX	Lubbock	33 40 06N	101 49 54W	50
125.8	TX	Grapevin	32 54 45N	097 05 28W	50
125.8	WA	Spokane	47 36 10N	117 39 30W	50
125.8	WY	Sheridan	44 36 44N	106 45 27W	50
125.8	WY	Lovell	44 49 00N	107 54 06W	20
125.8	Ontario	St Caths	43 11 00N	79 10 00W	50
125.85	FL	Jcksnvll	30 30 08N	081 41 29W	10
125.85	IA	Desmoins	41 31 49N	093 38 42W	10
125.85	NJ	Newark	40 41 XXN	074 09 XXW	50
125.85	OH	Cleveland	41 29 29N	081 43 33W	10
125.85	TN	Graham	35 50 30N	087 25 56W	50
125.85	VA	So Boston	36 40 30N	079 00 53W	10
125.85	WI	Milwauke	42 57 00N	087 54 02W	10
125.9	AZ	Dvsmnthn	32 10 15N	110 52 37W	10
125.9	CA	SanCarls	37 30 38N	122 14 27W	10

TABLE B-1

(Page 10 of 12)

Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.9	FL	Opalocka	25 54 40N	080 16 50W	50
125.9	GA	Atlanta	33 22 50N	084 18 00W	50
125.9	KS	Hutchnsn	37 55 24N	097 54 14W	20
125.9	KS	Hutchnsn	37 59 56N	097 37 00W	50
125.9	MD	Baltimor	39 11 XXN	076 41 XXW	50
125.9	MI	Lansing	42 46 21N	084 35 46W	10
125.9	MN	Farmngton	44 38 XXN	093 09 XXW	50
125.9	MN	Farmngton	44 38 15N	093 09 07W	20
125.9	MS	Jackson	32 19 XXN	090 04 XXW	50
125.9	MO	Stcharls	38 45 39N	090 31 13W	50
125.9	NV	Las Vegas	36 05 XXN	115 10 XXW	50
125.9	PA	Pttsbrgh	40 30 XXN	080 12 XXW	50
125.9	TX	Temple	31 09 10N	097 24 23W	50
125.9	WA	Seattle	47 28 18N	122 18 16W	50
125.9	WA	Mcchord	47 08 44N	122 28 05W	50
125.9	WV	Wheeling	40 10 49N	080 38 24W	10
125.9	Quebec	Val D'or	48 03 00N	077 47 00W	50
125.9	Newfoundland	Gander	48 57 00N	54 34 00W	50

TABLE B-1

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Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
125.95	CO	Denver	39 44 12N	104 43 30W	50
125.95	LA	Shrevprt	32 38 30N	093 32 50W	50
125.95	NJ	Robbnsvll	40 12 08N	074 29 44W	10
125.95	NY	Rochestr	43 07 35N	077 40 01W	10
125.95	OH	Columbus	39 59 56N	082 54 19W	50
125.95	VA	Richmond	37 30 27N	077 19 19W	10
126	CA	Oakland	37 42 46N	122 13 29W	10
126	CA	San Pedro	33 44 44N	118 20 04W	20
126	CA	Palmdale	34 36 11N	118 05 04W	20
126	CA	Los Angeles	33 57 44N	118 22 38W	10
126	DE	Wilmngtn	39 40 56N	075 36 58W	50
126	FL	Tampa	27 57 51N	082 31 35W	50
126	GA	Columbus	32 31 05N	084 56 30W	50
126	HI	Haleakal	20 42 31N	156 16 03W	50
126	IL	Alton	38 53 23N	090 03 28W	10
126	KS	Olathe	38 51 15N	094 44 11W	10
126	LA	N Orleans	30 23 40N	089 53 07W	50

TABLE B-1

(Page 12 of 12)

Frequency In MHz	State or Province	City	Latitude	Longitude	Transmitter Power In Watts
126	OR	Newberg	45 21 12N	122 58 37W	10
126	SC	Charlstn	32 53 45N	080 02 15W	50
126	TX	Ft Worth	32 56 35N	097 21 06W	50
126	TX	El Paso	31 51 51N	106 29 24W	50
126	TX	El Paso	31 40 53N	106 11 50W	50
126	UT	Ogden	41 11 46N	112 01 16W	10
126	VA	Roanoke	37 18 33N	080 09 36W	50
126	WI	Wausau	45 01 34N	089 35 18W	50
126	Alberta	Edmntn'	53 19 XXN	113 35 XXW	20
126	Ontario	Sarnia	42 54 00N	082 18 00W	50
126	Quebec	Mt Joli	48 36 00N	068 12 00W	1000
126	Quebec	Sept Ils	50 13 00N	066 16 00W	50

APPENDIX C

COVERAGE AREAS OF EXTENDED RANGE VHF STATIONS IN THE US, CANADA, AND THE NORTH ATLANTIC REGION

FIGURES C-1 through C-6 show the coverage areas of the extended range VHF stations in the US and Canada. FIGURE C-7 shows the coverage areas of the extended range VHF stations in the North Atlantic Region.

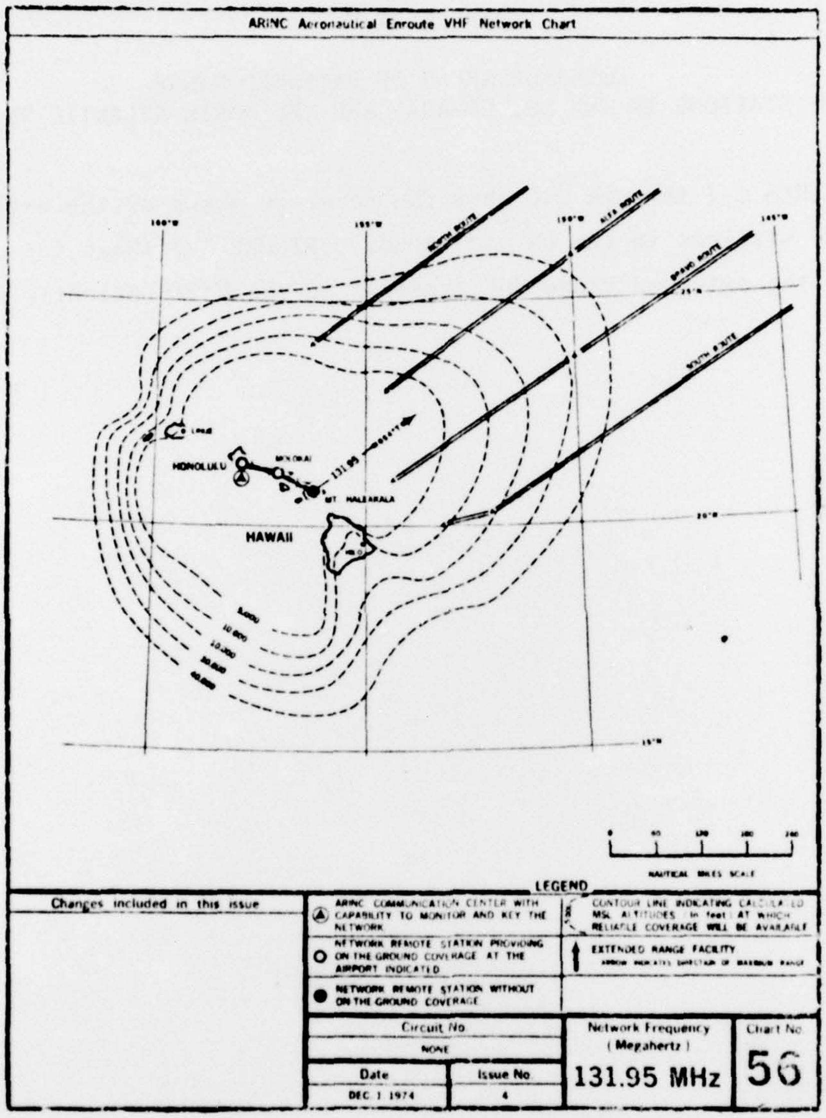

FIGURE C-1. EXTENDED RANGE VHF TRANSMITTERS IN THE US AND CANADA, HAWAIIAN ISLANDS.

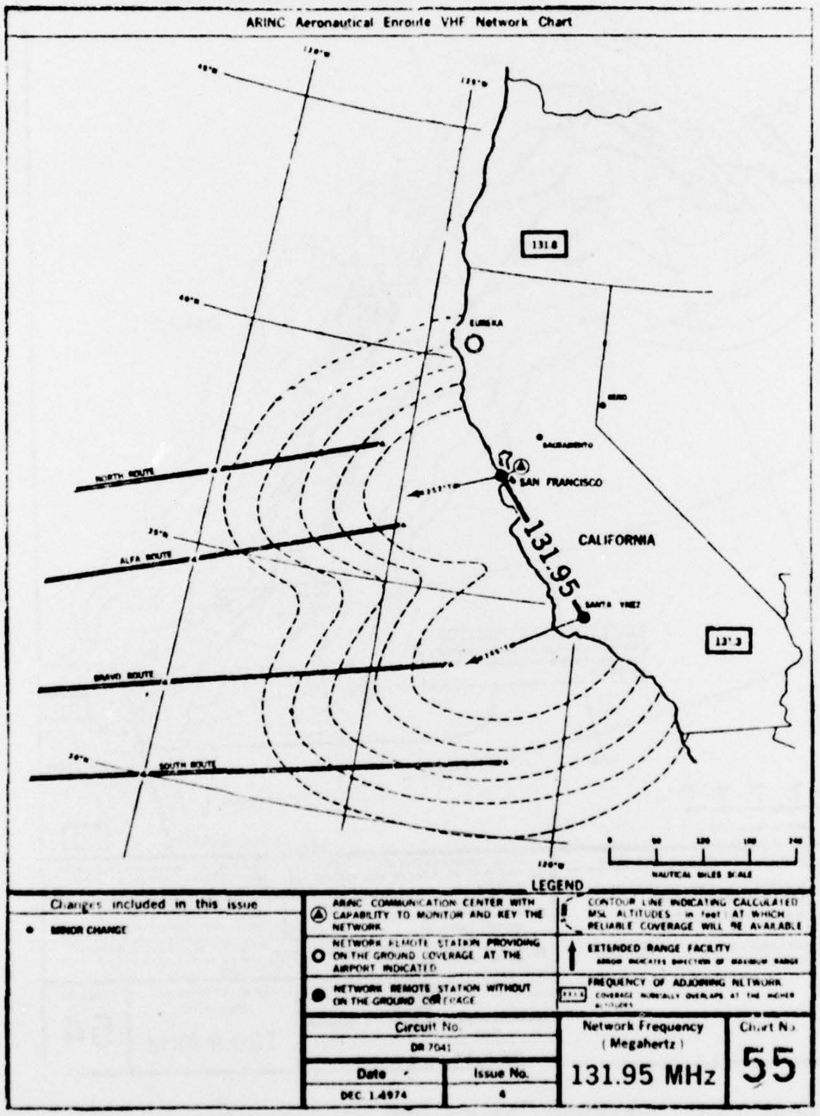

FIGURE C-2. EXTENDED RANGE VHF TRANSMITTERS IN THE US AND CANADA, WEST COAST US.

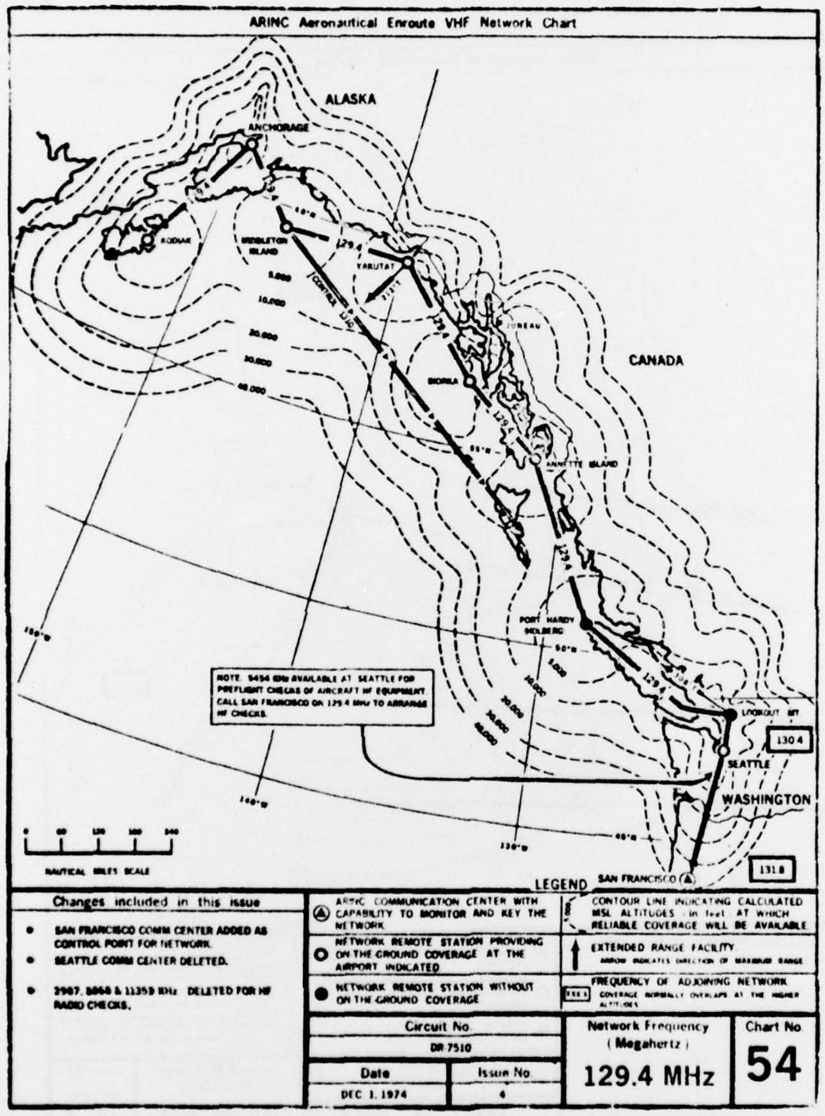

FIGURE C-3. EXTENDED RANGE VHF TRANSMITTERS IN THE US AND CANADA, CANADA AND ALASKA.

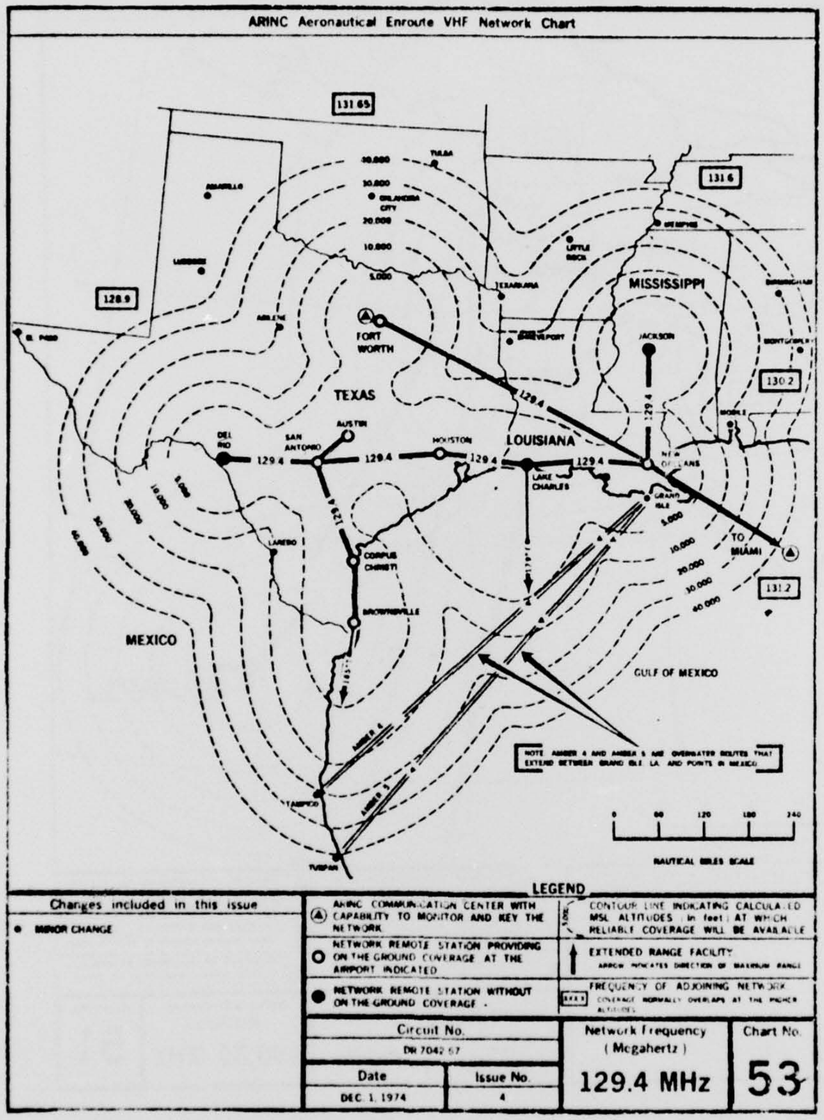

FIGURE C-4. EXTENDED RANGE VHF TRANSMITTERS IN THE US AND CANADA, GULF COAST.

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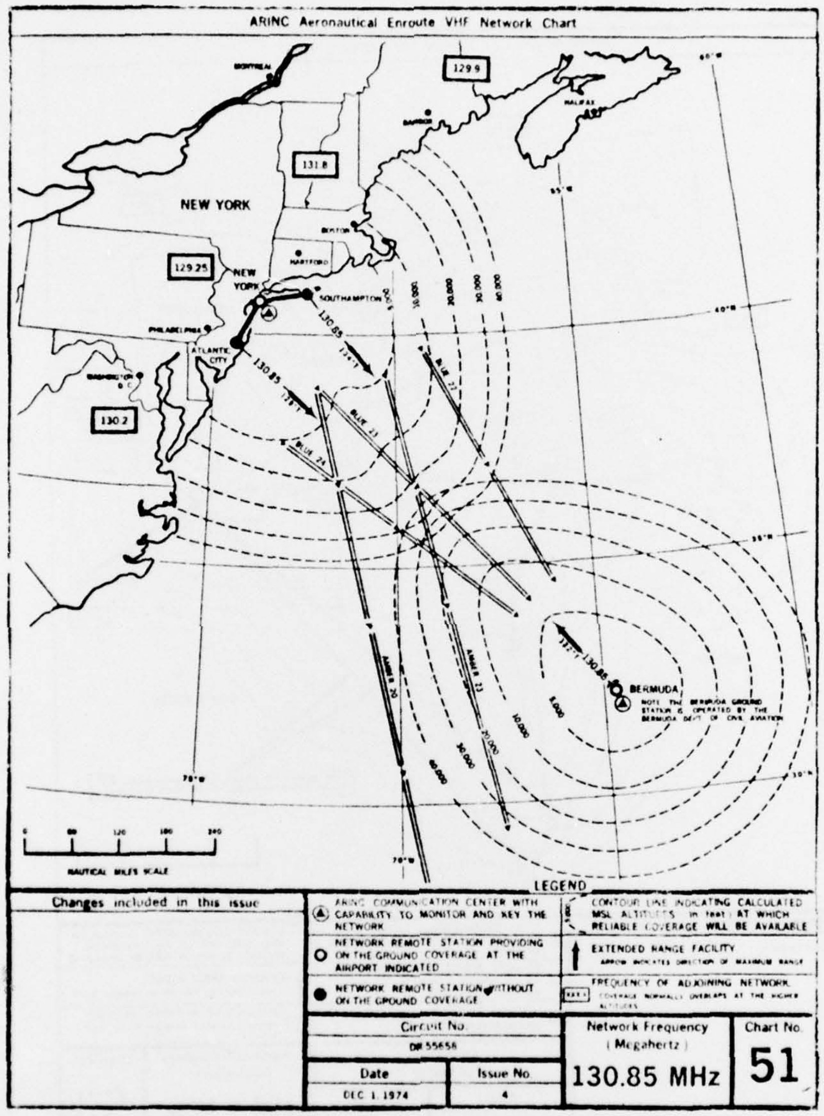

FIGURE C-5. EXTENDED RANGE VHF TRANSMITTERS IN THE US AND CANADA, EAST COAST, US.

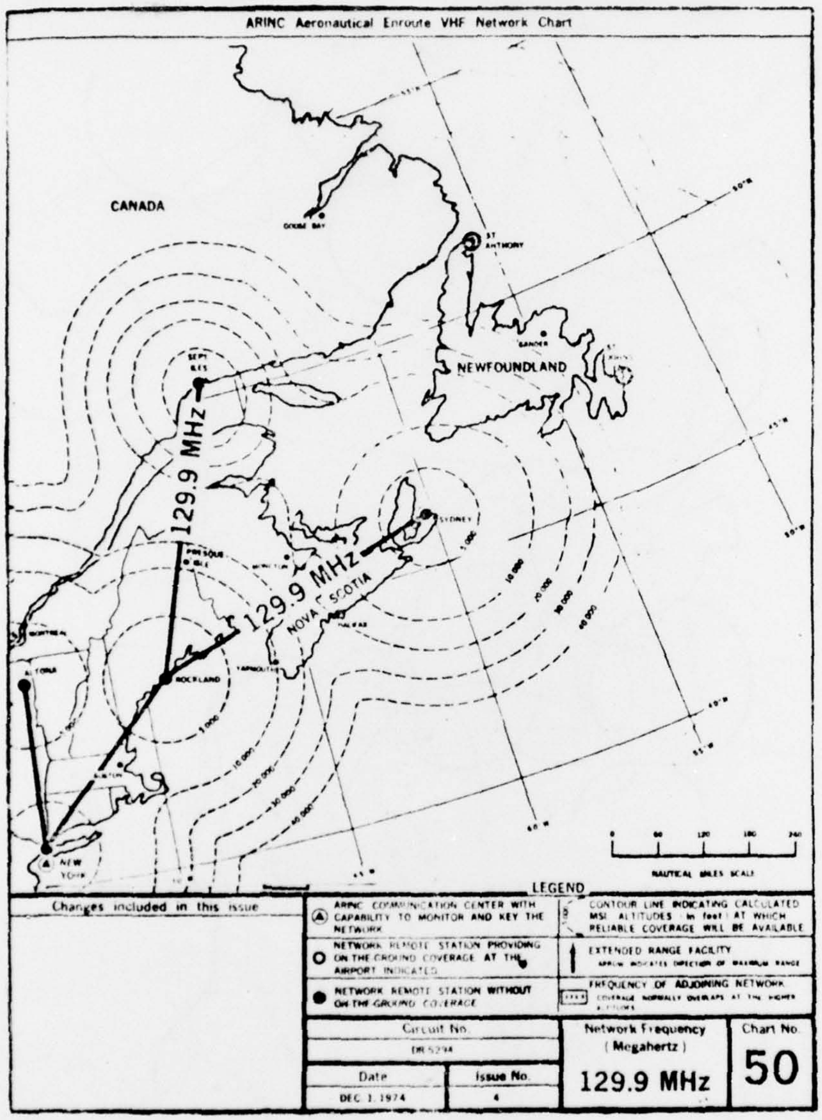

FIGURE C-6. EXTENDED RANGE VHF TRANSMITTERS IN THE US AND CANADA, EAST COAST, CANADA.

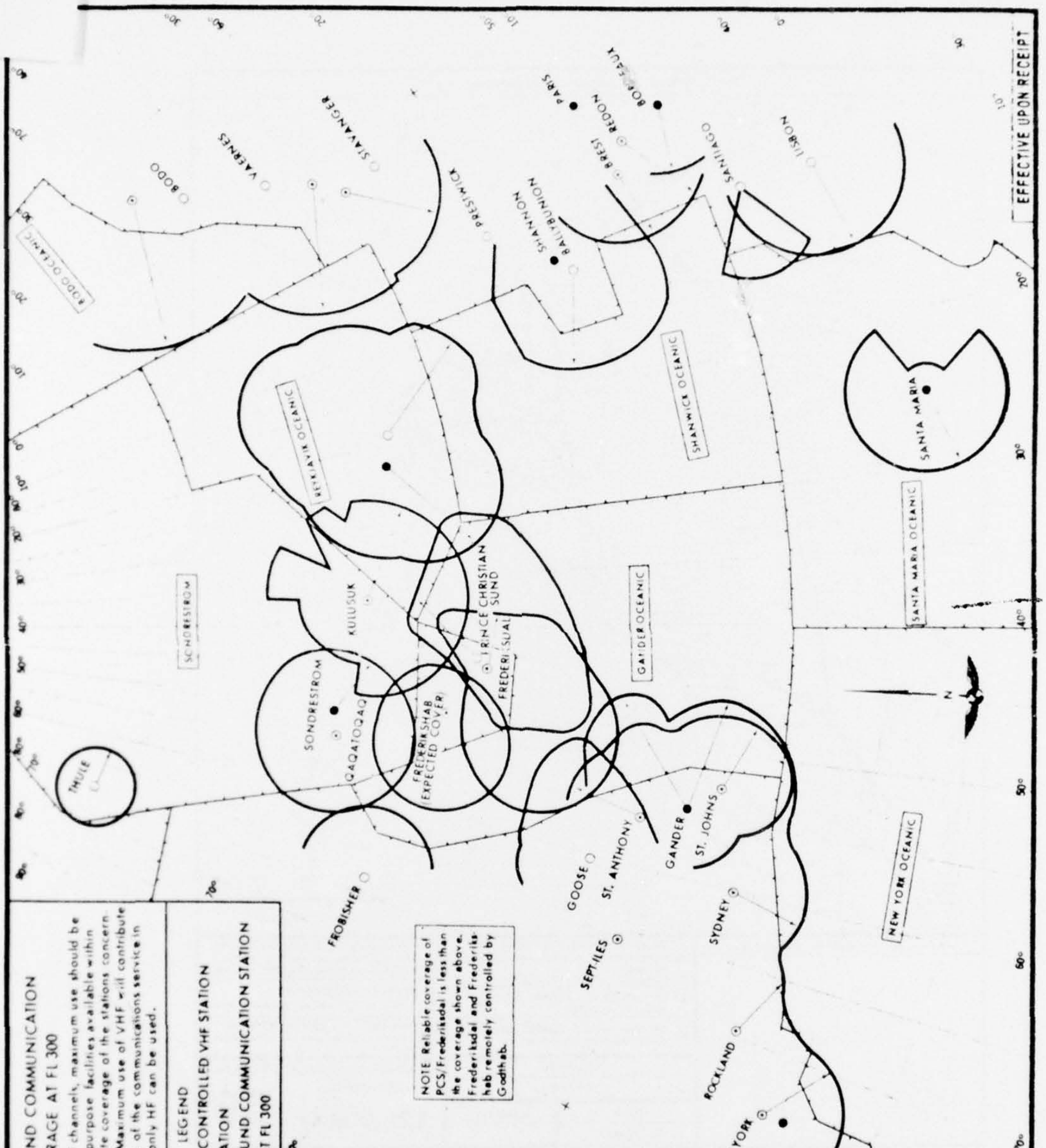

FIGURE C-7. EXTENDED RANGE VHF TRANSMITTERS IN THE NORTH ATLANTIC.

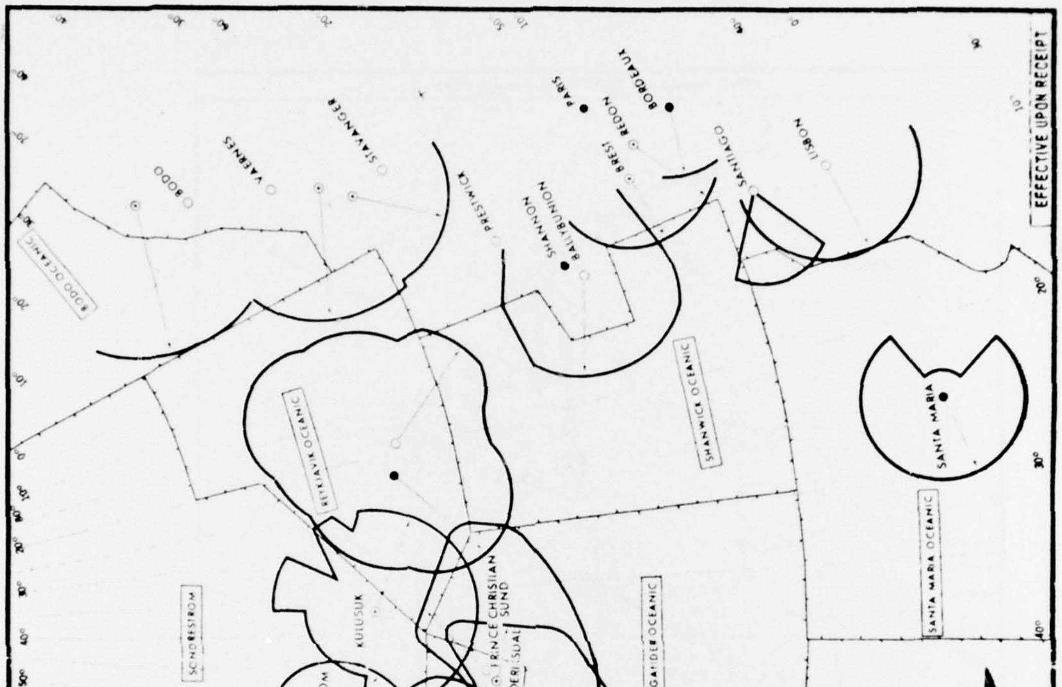

FIGURE C-7. EXTENDED RANGE VHF TRANSMITTERS IN THE NORTH ATLANTIC.

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